

HYDRAULIC TESTING OF
MULTIPLE SIPHON
GENERATOR INTAKES

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PREFACE

This is the final report describing the results of physical model studies undertaken by Western Canada Hydraulic Laboratories to investigate hydraulic limitations of using several modular siphon generator intakes in close proximity to one another.

The project was undertaken to simplify preparation and to increase reliability of prefeasibility design and cost estimates for low head power developments using pre-engineered and commercially available siphon generator units. The information is expected to greatly enhance sales promotion and development of such units by Canadian producers for sales in Canada and overseas.

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ABSTRACT

Physical model studies were undertaken at 1:15 scale to investigate hydraulic features of locating intakes to several modular siphon generator units in close proximity to one another. The project was to simplify preparation and increase the reliability of prefeasibility designs and cost estimates for low head power developments which used pre-engineered and commercially available siphon units.

Experiments were performed to determine the range of conditions over which the intakes could be operated without undue vortex formation. Effectiveness of basic vortex prevention techniques were examined. Tests were carried out to gauge the effects of angle of approach, discharge, submergence, bottom clearance and approach velocity on hydrostatic and differential horizontal and vertical pressure imbalances across the intake.

It was concluded that the greatest feasible number of banked siphon modules would benefit the performance of the system as a whole as the least favorable operating conditions generally occurred at the upstream intakes and at high siphon discharges.

An approach channel forming 120° angle with the intake panel proved to be the overall optimum configuration of the three approach directions tested. Improvements to intake flow conditions could be achieved by minimizing corner effects, increasing submergence depth and locating the bottom of the intakes as close to the approach channel floor as was feasible with respect to sedimentation or other concerns. The most adverse operating conditions occurred for a 180° high velocity approach channel flow bypassing the intake panel which produced a strong recirculation inside the siphon modules.

EXECUTIVE SUMMARY

Physical model studies were undertaken at 1:15 scale to investigate variations in flow conditions at the entrances to adjacent rectangular intakes spaced uniformly along a vertical wall and drawing from a common approach flow. The studies were to evaluate the feasibility of, and to determine factors which might limit the operation of, several modular siphon generator units in close proximity to one another.

Experiments were performed to determine the range of conditions over which the intakes could be operated without undue vortex formation and to investigate the effectiveness of basic vortex prevention techniques. Tests were carried out to gauge the effects of angle of approach, discharge, submergence, bottom clearance and approach velocity on hydrostatic and differential horizontal and vertical pressure imbalance across the intake.

The best overall approach conditions to the intakes were achieved when the approach canal was aligned most directly to the intake conduit centerline. The corner angles where the approach channel sides meet the intake wall require proper design to eliminate vortex formation. Improvements to intake flow conditions could be achieved by minimizing corner effects, increasing the submergence depth, and locating the intake as close to the channel bed as is consistent with structural restraints and siltation concerns. The most adverse operating conditions occurred for a 180° high velocity approach channel flow bypassing the intake panel which produced a strong recirculation inside the siphon modules.

The most unfavorable operating conditions occurred at high siphon discharges and in upstream intakes. Installation of a large number of relatively small units to produce a required power output would therefore produce more even operating conditions between the units than would installation of fewer but larger units and would benefit the performance of the generator system as a whole.

CONCLUSIONS

The following conclusions have been drawn from this study:

1. Along a bank of parallel intakes, the most upstream few intakes experience the most detrimental flow conditions with respect to drawdown of the water surface, vortex formation and imbalance of pressures across the entrance.
2. Placing siphon generator intakes adjacent to each other along a straight vertical wall would not necessarily affect their individual performances if adequate concern were given to their spacing, approach flow conditions and entrance design. Physical model studies should be employed in the design stage of a specific installation.
3. As the most upstream few intakes experience the worst flow conditions and pressure imbalance effects, it may be better to use a long series of relatively small siphon generator units to achieve a desired power output rather than to use a small number of larger units.
4. Severe vorticing at vertically faced intakes which is produced by conditions of high intake flows and low submergence can be minimized through the use of horizontal plates above the intakes. The required width of the plate would depend on the submergence and intake discharge. The plate must span the entire bank of intakes.
5. The effects of intake submergence on the discharge levels which can be drawn from a rectangular vertical intake of the design tested without incurring excessive vortex action are shown in Figure 7.
6. More uniform flow conditions are developed across a bank of parallel intakes when flow approaches more directly in line with the intake centrelines than when it approaches at a sharp angle or perpendicular to the centreline.

7. The wall layout at the ends of a long bank of intakes has a significant effect on vortex formation at the end units.
8. A moderate increase of flow velocity in a closed approach channel generally reduced the variation in hydrostatic pressures measured along the line of intakes. Increased approach velocities reduced the horizontal pressure differential measured across individual intakes at 120° approach angle but increased both horizontal and vertical pressure differentials at 150° approach angle.
9. An increase in submergence has the effect of reducing the horizontal dynamic pressure differential across the intake entrance at moderate to high intake flows, and alleviates the vertical pressure imbalance at low to moderate intake discharges.
10. High velocity flows passing by the face of the intakes may cause flow recirculation inside the intake conduits. The width of a typical recirculation zone decreases along the downstream axis and is reduced at lower stream approach velocities. Approach velocities of less than about 1 m/s passing by the intakes are not likely to cause significant adverse effects in the conduits.
11. A reduction in bottom clearance produced a slight improvement in hydrostatic pressure distribution across the series of banked intakes for most conditions tested.
12. Differential pressure fluctuations occurred across the intakes during all operating conditions. The period of the fluctuations increased with increasing intake discharges, reaching the 2 to 3 second range at $40 \text{ m}^3/\text{s}$.

3.0 INTRODUCTION

3.1 Use of Siphon Generators

Siphon turbine generators are being increasingly used in eastern Canada as a relatively inexpensive method of producing hydroelectric power where an existing low differential head situation has been developed. The siphon generator lifts flow from a forebay, passes it through a turbine and drops it down to the tailrace, fully utilizing the available head differential without incurring the need for expensive excavations and below-ground structures.

Structural, turbine and engineering costs required to produce power from a given situation may in many places be reduced through use of several standard, pre-engineered modular siphon generator units in place of one or more specially designed site-specific conventional generators. The use of a large number of adjacent siphon turbines has advantages of simplicity of design and maintenance as well as of speed of construction and ease of transport. Recent design studies have indicated that for heads of 4 m to 13 m, it was possible in 1987 to use a series of turbines and modular generators to produce power for as low as \$2,000/kw capital cost.

3.2 Potential Problems with Adjacent Units

It is important with low head installations that all extraneous head losses such as are associated with approach flow irregularities, intake losses and vortex formation are minimized as these losses form a greater proportion of the available head than would be the case for high head installations. The total head available for power generation at any intake entrance will be a combination of the static head at the entrance plus the velocity head through the entrance. The total head will be the upstream head minus losses due to acceleration and turbulence in the curving approach flow, a static head loss due to starvation of flow to the unit by its neighbouring units and a further velocity head loss through the intake due to eddying around the external support structures and the likely unbalanced intake velocity distribution.

Losses inside the intake are a function not only of the average entrance flow velocity but also of the velocity distribution across the intake conduit. Reduced head losses are achieved with low average intake velocities and uniform velocity distributions.

There is insufficient information presently available to multiple siphon generator unit designers for optimizing the spacing and alignment of the siphon intakes with respect both to reducing potential power losses and added construction costs. The effects of intake approach angle, thickness of dividing walls, size of vortex prevention devices, submergence, approach velocity and other similar factors are not yet known.

The effects of such variables on power output are significant in low head installations where even small system head losses subtract an appreciable part of the total head available for power generation. The effect of such factors may be readily assessed, however, through appropriately designed physical model studies.

OBJECTIVES

The objectives of the physical model studies described herein were:

- i to evaluate the effect of approach flow speed; approach flow direction; intake velocity; intake submergence and bottom clearance on vortex formation and on intake velocity distribution;
- ii to assess the degree of flow starvation and consequent reduction in head between adjacent intakes;
- iii to determine suitable design conditions for minimizing vortex formation and head losses over a wide range of operating conditions.

5.0 MODEL STUDY

5.1 Model Scale

A 1:15 scale model layout was adopted to investigate the interrelated effects of eight adjacent parallel intakes drawing horizontally from a vertical wall. These conditions were considered to be typical of simple structures along the banks of rivers or canals or on impounded waterways. Flow conditions through intakes are governed by the approach flow momentum, the drawdown in surface elevation produced by flow to adjacent intakes, the pressure drop through the intake and by eddying and/or other head losses around entrance support walls and through the bellmouth. In operating a physical model of an intake, similitude of the Froude number, a mathematical parameter relating flow velocity to hydrostatic head, must be maintained between model and prototype to ensure that the relative gravitational and momentum effects are accurately reproduced.

Eddying, vortex development and head losses at an intake which are due to turbulence are functions of the Reynolds number, a parameter relating viscous energy losses to flow velocity. It is not possible to maintain similitude of both Froude and Reynolds numbers at other than full scale if water is to be considered in both model and prototype.

The undisturbed model scale of 1:15 was selected for the study in order to maximize study discharges with existing equipment while maintaining flow at sufficiently high Reynolds number that viscous energy losses did not affect model results. Maintaining Froude number similitude in conjunction with the 1:15 model scale gave the other following relationships:

<u>Characteristic</u>	<u>Relationship</u>	<u>Scale</u>
Length	L	1:15
Depth	L	1:15
Area	L^2	1:225
Velocity	$L^{1/2}$	1:3.87
Time	$L^{1/2}$	1:3.87
Discharge	$L^{5/2}$	1:871
Pressure	L	1:15

Unless noted otherwise, all measurements in this report are given in equivalent full-scale dimensions.

5.2 Model Description

The forebay and approach canal section of the model were enclosed within 15 m (0.6 m in model) high waterproofed block walls, Figure 1. Water was introduced through a diffuser at the upstream end of the model and guided to and/or past the intakes by removable interior block walls, Figure 2A. The intake bottom clearance could be varied by raising the floor elevation with 1.5 m high (10 cm) removable concrete blocks. Water level through the contained area was controlled by a tilting weir at the downstream end.

Eight parallel intakes opened horizontally out of a clear plastic section in the side of the contained area, at a centreline height of 3.6 m above the basin floor, Figure 2B. The intake centrelines were spaced 4.6 m laterally apart, leaving a 2.2 m thick dividing wall between adjacent conduits, Figure 3. The rectangular intake openings were 1.8 m high and 2.4 m wide as based on a unit design by Galt Energy Systems. Vertical intake corners were rounded to 0.270 m radius and horizontal corners were rounded to 0.375 m radius. The rectangular conduit sections ran for 5.25 m back from the face of the wall, then connected to 24.8 m long by 2.3 m diameter ABS pipes leading to individual metering orifices, control valves and a common pump suction chamber.

Flow was recirculated from the suction chamber through orifice meters and control valves back to the outlet diffuser by 15 kw and 18 kw centrifugal pumps. Excess water bypassing the intakes during tests with 180° approach flow direction was supplied by a 75 kw pump.

5.3

Instrumentation

Piezometer tapings (Pressure tap A, Figure 3) were located in the vertical plastic wall at a distance of 90 cm below the centre of each conduit floor to measure the static pressure at each intake and to show any reduction in hydrostatic head, or flow starvation, between units. Further vertical and horizontal tapings were located in all the sidewalls of the conduits at a distance of 0.9 m back from the vertical wall to determine any imbalance in flow contraction on opposite sides of the intakes. All piezometer taps lead through plastic tubing to a valved manifold and differential transducer arrangement, Figure 4A. Pressures were measured by Celesco pressure transducers having an accuracy of $\pm 5\%$ over a prototype pressure range of 0 - 15 psi. Pressures were read by digital voltmeter and recorded, along with instantaneous fluctuations, on a Brush chart recorder.

A slot was cut in the ceilings of Intakes no. 1, 3, 5 and 8 at a distance of 1.65 m behind the vertical wall in order to accommodate a sliding bar holding a directional Pitot tube, Figure 4B. Pitot tube readings were accurate to $\pm 5\%$.

Flows through each intake conduit were measured by machined plexiglass orifice plates. Total flows from the pumps were metered by machined 14 cm diameter orifice plates having a metering accuracy of $\pm 2\%$ in the 20 cm diameter pump lines.

Water surface levels determining intake submergence and channel depth were measured by Lory point gauges and were accurate to ± 5 cm prototype.

6.0 TEST PROGRAM

6.1 Testing Sequence

The test program was developed to determine the effects of operating several adjacent intakes with variations in the following conditions:

- i) angle of approach flow
- ii) discharge
- iii) intake submergence
- iv) bottom clearance
- v) approach channel flow velocity.

Tests were carried out in 3 stages with the approach flow at 180° (i.e., parallel) to the vertical intake face and at 150° and 120° to the face of the intakes. Intake flows in a range between $5 \text{ m}^3/\text{s}$ and $40 \text{ m}^3/\text{s}$ per intake were examined. Engineering sources in the power industry advised that flows of $20 \text{ m}^3/\text{s}$ to $30 \text{ m}^3/\text{s}$ per intake would be desirable for potential installations. The number of intakes operating at the higher discharges was limited by model pumping considerations.

The first tests in each stage investigated the range of conditions over which the intakes could be operated without undue vortex formation. The effectiveness of basic vortex prevention techniques were then examined to see whether or not the operating range of the intakes could be extended through addition of simple inexpensive structural modifications.

Although investigations were made into the effects of vortex eliminating devices, these were not installed for any of the main series of tests. All tests were run without any vortex prevention devices for more effective inter-comparison of test results. The list of tests and combinations of conditions examined is given in Table 1. Groupings of test conditions which allowed comparison of the various factors studied are given in Table 2. Observed pressures and intake velocity measurements are listed in Appendices A and B respectively.

Testing Procedure

To start each test, the water level in the model was set for a given intake submergence. Submergence was defined as the head of water over the soffit of the intake conduit, Figure 3. Tests were run initially at low intake flows and then gradually increased while vortex conditions were recorded for each flow increment. Vortex severity was documented on a standard laboratory scale of 1 to 5 covering the range between (1) surface dimples and (5) steady air core vortices, Figure 5. Dye injections were used to determine flow patterns in the vicinity of the intake entrance and inside the rectangular conduit.

Differential pressure measurement and flow metering devices were air bled at the beginning of each test period. Pressure transducers were calibrated daily against atmospheric and known hydrostatic pressures to guard against possible zero drift.

The total suction discharge and flow withdrawn from each intake were adjusted iteratively until the desired test conditions were attained. Flows through each intake were well balanced for all test discharges up to $20 \text{ m}^3/\text{s}$. For test discharges greater than $20 \text{ m}^3/\text{s}$, intake flows were initially balanced at that level and the suction flow was then increased until the total required withdrawal rate was reached. Some variation between intake flows may have occurred at these higher discharges although efforts were made to equally distribute the total suction discharge between the two pumps. A qualitative assessment of the channel flow patterns and the vorticity at the intake entrance were recorded.

A zero differential pressure trace on the Brush chart recorder was produced through bypassing the transducer assembly. Horizontal and vertical pressure signals were then recorded for each intake in turn, followed by the measurement of hydrostatic pressures at the centerline of every intake, Figure 6.

Local intake velocities were measured at mid-height and at five equidistant positions spanning the cross-section of alternating intakes for selected tests.

7.0 VORTEX PREVENTION

7.1 Prevention Techniques

Vortex suppression tests were run to eliminate severe air entrainment into the intakes during high flows at low submergence. Very smooth transitions between the bellmouths and the vertical panel face were required to minimize flow separation just inside the intake entrance.

With an approach flow at 180 degrees (ie. parallel) to the face of the intakes, it was observed that the most abrupt change in flow direction required for flow to enter the intakes occurred at the most upstream unit. Flow to each subsequent downstream unit was drawn from "streamlines" which had originally been progressively further out into the upstream channel and which therefore underwent progressively lower angular accelerations and approached their respective intakes at less acute angles to the intake centrelines. This observation was consistent for all approach angles studied.

Vortex prevention techniques were studied with flows between $30 \text{ m}^3/\text{s}$ and $40 \text{ m}^3/\text{s}$ per intake, a submergence of 1.2 m and a river discharge flowing at 180° to the intake panel. Class 5 vortices were produced outside the entrance of the first open intake followed by a class 3 vortex at Intake no. 2 and less severe vortices in the remaining operating intakes at both flows. This situation was considered to represent a very severe combination of conditions. Several metal and plastic gratings of 1.5 m width with square openings from 8 cm to 40 cm per side were suspended horizontally at various depths above the intakes. No significant reduction in air entrainment was observed. The gratings were also placed perpendicular to the channel flow resting against the intake panel upstream of Intake no. 1 to reduce approach circulation. While this appeared to produce a slight decrease in the severity of vortex action the air entrainment was not reduced to acceptable levels.

A solid full length horizontal plate protruding 1.5 m out from the wall just above the invert was found to suppress all air entrainment during the $30 \text{ m}^3/\text{s}$ discharge conditions. The width of the horizontal plate had to be increased to 2.0 m over the full length of the intakes immediately above the upper curved

entrance radius to prevent air entraining vortices at intake flows of $40 \text{ m}^3/\text{s}$. When the plate did not span the entire length of intakes, severe vortex action occurred at the first available unprotected intake.

7.2 Critical Flows for Vortex Prevention

7.2.1 Effect of Submergence

Tests were conducted to establish the maximum flows which could be withdrawn through each intake without vortex formation for given submergence and approach angle conditions without the use of vortex suppression devices. The threshold of unacceptable suction flow was considered to be the appearance of occasional small class 3 vortices. Comparisons between previous models and corresponding full scale observations have shown that, due to viscous scale effects, vortex formation at full scale is always stronger than is observed in a small scale model. The intake most sensitive to vortex formation with increasing flows was invariably the first operating upstream intake.

The effect of submergence on the critical intake flow for a 180° approach channel is shown in Figure 7. Class 3 vortices were noted during flows greater than $25 \text{ m}^3/\text{s}$ with a submergence of only 1.2 m, whereas a 2.4 m submergence restricted class 3 vortex formation to intake discharges greater than $45 \text{ m}^3/\text{s}$.

Previous studies (Acres, 1987; Gordon, 1970) have shown that the minimum submergence for a given design flow is dependent on the intake geometry. The threshold discharges as determined in the present test series and given in Figure 7 are valid for intake configurations similar to those described in Section 5.2 if class 3 vortices are considered tolerable. The approximate empirical relationship proposed for 180° angle of approach by Gordon, 1970, after a review of existing hydroelectric intakes required significantly more submergence than was found for "critical" conditions in this study. This difference may result from different assessments of the "critical" strength of a vortex as well as from entrance conditions.

7.2.2 Effect of Approach Angle

The maximum intake discharge at which vortex activity remained within acceptable limits varied for different channel approach angles. With a 180° approach flow, class 3 vortices were produced at a critical discharge of only $25 \text{ m}^3/\text{s}$ for a 1.2 m submergence depth and moderate approach velocity whereas the critical discharge was increased to $31 \text{ m}^3/\text{s}$ with a 120° angle of approach but otherwise similar conditions.

Vortex formation was also found to be dependent on approach velocity in the channel. At high approach velocities through a narrow channel, class 3 vortices were produced at lower intake flows than when the approach velocity was reduced. During tests with a 120° approach flow direction, the critical discharge of $31 \text{ m}^3/\text{s}$ at a 0.8 m/s approach flow velocity was reduced to $16 \text{ m}^3/\text{s}$ when the channel velocity was increased to 1.8 m/s at the same submergence.

The maximum intake discharge for a 150° channel approach direction depended on the boundary conditions surrounding the two outermost intakes. A highest critical discharge of $28 \text{ m}^3/\text{s}$ per intake was attained with only the first six intakes in operation and with the placement of a baffle block adjacent to Intake no. 6 in order to reduce the acute angle between the opposite forebay wall and the end of the intake panel. Without the baffle block in place, severe vortices formed off the opposite wall near the angled corner.

The distance between the baffle block and the intake entrance also played a role in achieving the maximum acceptable discharge. The weakest vortex conditions were developed when the block was placed directly alongside the downstream end of the intake. When Intake nos. 2 to 7 were functioning under the same conditions, the maximum individual flow decreased to $24 \text{ m}^3/\text{s}$ and was reduced even further when the baffle was withdrawn from the last intake. This showed that channel geometry near the outermost intake was a major factor in vortex formation for obliquely approaching channels.

Maximum intake flows for the 2.4 m submergence were not examined to the same degree as for the lesser submergence depth since in most cases the critical discharge was greater than the highest test flow of $40 \text{ m}^3/\text{s}$. Vortex scoping tests for the 150° channel approach angle did, however, again show the

effect of relative intake location on entrance flow conditions. The selection of operating Intakes nos. 4, 5, 6 and 7 was found to be superior to all other combinations of four adjacent intakes for a discharge of $40 \text{ m}^3/\text{s}$, and Intakes nos. 4, 5 and 6 produced the most favourable flow conditions for a $50 \text{ m}^3/\text{s}$ per intake discharge.

8.0 EFFECTS OF APPROACH FLOW CONDITIONS

8.1 Effect of Approach Angle

8.1.1 Hydrostatic Pressure Outside Intake

Of the three channel approach angles tested, the 150° approach angle appeared to produce the most uniform hydrostatic pressure distribution along the bank of siphon intakes. A near uniform water surface level across the intake panel was indicated by the hydrostatic pressure measurements for this approach direction under all test conditions. Some degree of flow starvation due to surface drawdown or vortex formation was indicated at the first three operating intakes for channels which approached from either 180° or 120° to the intake face.

Hydrostatic pressures measured directly below the intake centreline appeared to be affected by flow rotation, vortex formation and local flow accelerations associated with recirculation cells or uneven velocity distributions inside the intake conduits. Very low pressure measurements shown in Appendix A were non-representative of observed water surface profiles. Although these low pressures did not accurately represent the water surface level variations along the intake bank as was intended, they did show the relative occurrence of seriously detrimental hydraulic flow conditions. The large pressure variations, of over 1 m in some situations, could probably be reduced by a wider spacing and/or improved entrance design of the intakes. A typical comparison between hydrostatic pressure levels for different approach directions is shown in Figure 8A.

At discharges below $20 \text{ m}^3/\text{s}$, the 120° channel approach generally produced the poorest hydrostatic pressure distribution along the row of intakes of the three angles tested. Significant low pressures were measured at a greater number of intakes with this approach angle than with either 150° or 180° . At flows above $25 \text{ m}^3/\text{s}$, however, the effect of approach angle decreased. The 180° angle of approach produced the greatest variation in external hydrostatic pressure of the three approach angles tested at high discharges, Figure 8B.

In general, the downstream inner face of the intake was subject to greater horizontal pressure than the upstream face due to the impingement of the approach flow onto that face.

Two different analyses were made of the differential horizontal pressure measurements. The first analysis determined the worst case of horizontal pressure imbalance across any intake for a given set of test parameters. The second analysis was of the gradient in differential horizontal pressures across the whole series of siphon modules.

In the first analysis, higher lateral pressure differences were produced when flow approached at 180° along the face of the intakes than when approaching at 120° or 150° . The relatively high approach velocity of 2 m/s used during the 150° angle of approach test shown in Figure 8C may, however, have contributed largely to the high pressures measured at that angle as compared to the other approach directions with lower approach velocities. The intakes which suffered the greatest pressure imbalance were generally located in the middle third of the panel with pressure differentials decreasing towards the outward modules. With a 180° approach channel, the overall horizontal pressure imbalance was reduced and the location of the most severe conditions was shifted to the first two upstream intakes.

The 120° angle of approach produced the lowest differential horizontal pressures across the intakes. The variation in pressure imbalance along the intake panel at this flow approach angle was also least for all of the approach angles tested. It was noted that during intake discharges of $40 \text{ m}^3/\text{s}$, the horizontal pressure gradients for the three channel approach directions were similar, as at high discharges the approach flow velocity head was very small compared to the intake velocity head.

8.1.3 Differential Vertical Pressures

Throughout the test program it was noted that the ceiling of the intake module near the point of maximum flow contraction generally experienced larger pressure fluctuations than did the corresponding point on the floor of the intake. Fluctuations from the average pressure differential between the ceiling and the floor were typically ± 0.5 m with periods of up to 3 secs. The average period of pressure fluctuations at high discharge levels was longer than at low discharge levels.

The peak dynamic forces on the intake ceilings varied with different test parameters. As was found in the horizontal pressure analysis, the 120° channel approach produced a more uniform differential vertical pressure profile along the row of intakes under all intake discharges and submergence levels than did the 150° and 180° approach angles, Figure 9. The maximum heads acting on the intake ceilings with a 120° approach angle were consistently lower than those measured for other approach directions.

The average fluctuations in pressure differential between the ceiling and floor of each intake did not vary significantly between the different approach channel angles. The vertical head fluctuations, however, were amplified with channel approach directions of 180° and 150° , the latter being marginally worse, producing slightly higher and more frequent pressure peaks.

8.2 Effect of Approach Velocity

8.2.1 No Bypassing Flow

An increase in approach velocity produced by narrowing the channel walls for channels with closed forebays generally reduced the range of variation in hydrostatic pressures which were measured along the bank of intakes at lower approach velocities, Figure 10. At a 120° angle of approach, increasing the channel flow velocity reduced the degree of flow starvation to the first few

upstream intakes, Figure 10A. The faster current at the 150° approach angle had no significant effect on the hydrostatic pressure distribution across the intakes, Figure 10B, as the pressure variations were already low. The slight differences in static head were within the range of experimental error.

Increasing the flow velocity in the approach channel did not appear to affect the differential horizontal pressures across individual intakes in the same manner for all approach channel angles. For 150° and 180° channel approach directions, an increase in approach velocity increased the horizontal pressure imbalance across individual intakes without significantly altering the variation in differential pressures along the intake panel, Figure 11A. However, in the case of a 120° angle of approach, an increase in approach current was found to consistently reduce the differential horizontal pressures across the upstream intakes, thereby promoting a greater uniformity of differential horizontal pressures along the series of intakes.

An increase in approach flow velocity generally increased the head differential between the ceilings and floors of the intakes at a given intake discharge. Figure 11B shows that increasing the 120° approach channel velocity by 60% caused an increase in the average differential vertical head by approximately 12 cm at $40 \text{ m}^3/\text{s}$ intake flows.

8.2.2

Flow Passing Intakes

Additional tests with the 180° approach angle were undertaken to compare intake entrance conditions with a closed forebay versus those with a stream current passing the intake faces.

The effects of opening the forebay to allow channel flow to bypass the intake entrances as well as to increase the approach channel velocity were:

- i) Allowing flow past the intakes produced a more uniform hydrostatic pressure distribution along the intake panel at the three intake flows tested between $15 \text{ m}^3/\text{s}$ and $40 \text{ m}^3/\text{s}$, Figure 10C, Appendix A. The low hydrostatic pressure measurements at the upstream intakes were increased by the bypassing flow.

- ii) Vertical pressure differentials across individual intakes at a given discharge were increased when the main stream flowed past the intakes. Figure 11C shows that the typical maximum pressure fluctuations were increased by as much as 1.05 m for intake discharges of 40 m/s.
- iii) The bypassing flow changed the uniform pattern of differential horizontal pressures across the intake panel. A much greater horizontal pressure differential was measured across the upstream intakes than across the downstream intakes when the main flow was past the intakes.

A major recirculation zone formed along the upstream side of the intake modules during tests 180-17 & 18 when the main flow in the 180° approach channel bypassed the intakes, Figure 12. The extent of flow separation in the intakes depended on the velocity of the approach channel. For Test 180-17A, with a bypassing current of 3.2 m/s, a recirculation zone was observed in the first six intakes. Intake no. 1 was the most affected with the recirculation zone covering half the intake width and penetrating 4.5 m into the conduit. The severity of the flow disturbance in each intake decreased in the downstream direction. When the channel velocity was reduced to 2.1 m/s, only the first three upstream intakes showed signs of recirculation with narrower zones of flow separation.

Confetti traces showed that with a channel velocity of 2.1 m/s, a slow recirculating flow in the channel itself occurred immediately downstream of the last operating intake along the far side wall during bypassing flow tests. The intake withdrawal along the left side of the channel had been sufficient to pull the main flow stream away from the right wall, allowing the recirculation cell to form.

When the current was increased to 2.5 m/s, the recirculation zone was maintained although reduced in size. When the stream velocity was increased to approximately 3.1 m/s, there was no evidence of a recirculating flow but a large velocity gradient remained across the channel.

9.0 EFFECTS OF INTAKE LAYOUT

9.1 Effect of Intake Discharges

Since vortex strength is known to be affected by increasing entrance velocity, an increase in intake discharge was expected to produce an overall worsening of entrance flow conditions. Hydrostatic pressure measurements showed, however, that in general an increase in siphon flow did not adversely affect the hydrostatic head above the intakes and that in some cases an increase in discharge produced more equal hydrostatic pressures as measured below each intake along the panel.

Figure 13 shows the effect of intake discharge on hydrostatic pressure variations. In most cases, an increase in intake discharge resulted in higher and more uniform hydrostatic pressures as measured below the intakes along the intake panel.

A comparison of curves for increasing discharge but otherwise similar conditions in Figure 14 shows that increasing the discharge in all cases increased the difference in pressures on opposite horizontal sides of the intake. This resulted from a greater strength of flow impingement on the downstream face and more flow separation from the upstream face both with increasing entrance velocity (i.e. discharge) and increasing angle of approach. The greatest effect of these factors was noted at the more upstream intakes as flow into the downstream intakes was pulled from streamlines which had originally been further out in the approach channel and which had therefore been drawn into a better degree of alignment with the conduit centreline prior to reaching the intake entrance than was the case for flow to the upstream intakes.

Although the average differential vertical pressure across any intake did not vary significantly with a rise in intake discharge, the typical maximum pressure fluctuations were noticeably increased.

An increase in submergence depth did not appreciably affect hydrostatic pressures in front of the intakes under most test conditions. With low intake discharges the relative drop in pressures at intakes No. 2 and 3 was found to be consistently greater when the invert submergence was increased from 1.2 m to 2.4 m, Figure 15A. For intake flows $20 \text{ m}^3/\text{s}$ and greater, doubling the submergence had little effect on the water surface profile across the panel or the change in hydrostatic head between siphon modules, Figure 15B.

Increasing the level of submergence reduced the variation in horizontal pressure imbalance between the upstream and downstream faces of individual intakes. Figure 15C shows that the effects of increased submergence were more pronounced at high discharges when the intakes had the largest pressure head differentials. At low intake discharges of 5 and $15 \text{ m}^3/\text{s}$, raising the submergence level from 1.2 to 2.4 m did not substantially lower the overall magnitude of the horizontal pressure differentials along the series of intakes.

At low to moderate intake flows of up to $20 \text{ m}^3/\text{s}$, an increase in the submergence depth alleviated the vertical pressure imbalance in two ways, Figure 16:

- i) the average vertical pressure differential as well as the corresponding typical maximum fluctuations decreased slightly;
- ii) the variation in vertical pressure differentials between adjacent intakes was reduced so that the differential pressures were more uniform along the line of operating intakes. At higher discharges, an increase in submergence produced a greater reduction in vertical pressure differentials than occurred at low discharges but the variations in pressure differentials between adjacent intakes were not significantly changed.

Effect of Bottom Clearance

Experiments were undertaken to investigate the effect of bottom clearance from the intake floor to the channel bed on intake conditions. As a result of more streamlined bottom entrance alignment, the reduction in bottom clearance generally improved the hydraulic conditions at the intakes. Raising the channel bed increased the low hydrostatic pressures measured at the upstream intakes at flows of about $15 \text{ m}^3/\text{s}$, Figure 17, but did not affect the hydrostatic pressure distribution across the panel for intake discharges of $30 \text{ m}^3/\text{s}$ or greater.

Raising the channel bed reduced the horizontal and vertical pressure imbalance for conditions with a 180° approach channel but either had little effect or worsened conditions at other approach angles, Figure 18. For a given channel depth, it would therefore appear to be better to lower the level of the intakes so as to obtain the consequent improvements in surface vortex prevention and more even hydrostatic pressure distribution so long as sufficient bottom clearance is left to minimize any site construction or siltation problems.

REFERENCES

Acres International Ltd.; Evaluation of Syphon Performance, unpublished report prepared for Energy, Mines and Resources Canada; 1987.

Gordon, J.L.; Vortices at Intakes; Water Power, April 1970.

Reddy, Dr. Y.R. and Pickford, J.A.; Vortices at Intakes in Conventional Sumps; Water Power, March 1972.

TABLE I
TEST PROGRAM

Test	Approach Angle (Deg.)	No. of Intakes	Discharge Per Intake (m ³ /s)	Total Discharge (m ³ /s)	Approach Velocity (m/s)	Channel Depth (m)	Intake Submergence (m)	Velocity Measurement	Bypass Flow (m/s)
180-1	180	8	5	40	0.2	5.7	1.2		
180-2	180	8	15	120	0.7	5.7	1.2	x	
180-3	180	8	20	160	0.9	5.7	1.2		
180-4	180	6	25	150	0.8	5.7	1.2	x	
180-5	180	8	5	40	0.2	6.9	2.4		
180-6	180	8	15	120	0.5	6.9	2.4	x	
180-7	180	8	20	160	0.7	6.9	2.4		
180-8	180	5	30	150	0.7	6.9	2.4	x	
180-9	180	4	40	160	0.7	6.9	2.4	x	
180-10	180	8	5	40	0.3	4.3	1.2		
180-11	180	8	15	120	0.9	4.3	1.2	x	
180-12	180	6	25	150	1.1	4.3	1.2	x	
180-13	180	8	15	120	0.7	5.5	2.4	x	
180-14	180	8	20	160	0.9	5.5	2.4		
180-15	180	4	40	160	0.9	5.5	2.4	x	
180-16	180	4	40	160	2.8	5.5	2.4		1.36
180-17	180	8	15	120	3.2	4.3	1.2	x	1.75
180-18	180	6	25	150	2.5	4.3	1.2	x	0.72
150-1	150	8	5	40	0.5	4.3	1.2		
150-2	150	8	20	160	2.0	4.3	1.2	x	
150-3	150	6	25	150	1.8	4.3	1.2	x	
150-5	150	4	40	160	1.5	5.5	2.4	x	
150-6	150	4	40	160	1.5	5.5	2.4		
150-7	150	4	40	160	1.5	5.5	2.4		
150-8	150	5	25	125	2.4	4.3	1.2	x	
150-9	150	4	40	160	2.4	5.5	2.4	x	

TABLE I (Cont'd)

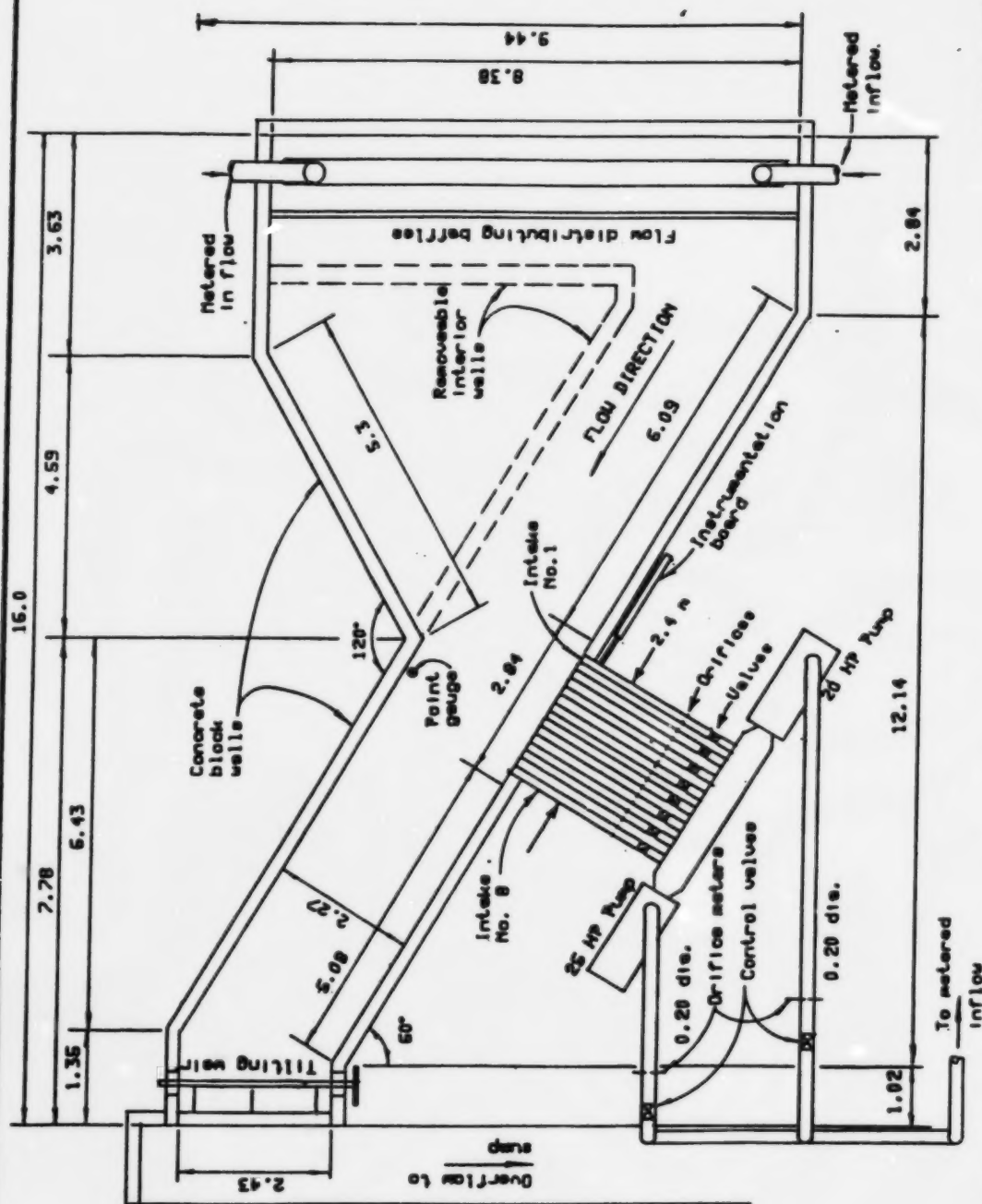
Test	Approach Angle (Deg.)	No. of Intakes	Discharge Per Intake (m ³ /s)	Total Discharge (m ³ /s)	Approach Velocity (m/s)	Channel Depth (m)	Intake Submergence (m)	Velocity Measurement	Bypass Flow (m/s)
120-1	120	8	5	40	0.3	4.3	1.2		
120-2	120	8	15	120	0.9	4.3	1.2	x	
120-3	120	8	20	160	1.2	4.3	1.2		
120-4	120	5	30	150	1.1	4.3	1.2		
120-5	120	8	15	120	0.7	5.5	2.4	x	
120-6	120	5	30	150	0.9	5.5	2.4	x	
120-7	120	4	40	160	0.9	5.5	2.4	x	
120-8	120	8	15	120	0.5	6.9	2.4	x	
120-9	120	5	30	150	0.8	5.7	1.2	x	
120-10	120	5	30	150	1.7	4.3	1.2	x	
120-11	120	5	30	150	1.4	5.5	2.4	x	
120-12	120	4	40	160	1.4	5.5	2.4	x	
120-13	120	5	30	150	1.3	5.7	1.2	x	
120-14	120	5	30	150	1.1	6.9	2.4	x	
120-15	120	4	40	160	1.2	6.9	2.4	x	

TABLE 2

COMPARATIVE TEST GROUPS

Intake Flow (cumecs)	Submergence (m)	Test Nos.
<u>Effect of Angle of Approach</u>		
5	1.2	180-10, 150-1, 120-1
15	1.2	180-11, 120-2
15	2.4	180-6, 120-8; 180-13, 120-5
20	1.2	180-3, 150-2, 120-3;
25	1.2	180-12, 150-3
40	2.4	180-15, 150-5, 120-7; 180-16, 150-9, 120-12
<u>Effect of Approach Velocity</u>		
15	1.2	180-11, 180-17
25	1.2	150-3, 150-8
30	1.2	120-9, 120-13; 120-4, 120-10
30	2.4	120-6, 120-11
40	2.4	150-5, 150-9; 120-7, 120-12; 180-15, 180-16
<u>Effect of Submergence</u>		
5		180-1, 180-5
15		180-2, 180-6; 180-11, 180-13; 120-2, 120-5
20		180-3, 180-7
30		120-4, 120-6; 120-13, 120-14; 120-10, 120-11
<u>Effect of Bottom Clearance</u>		
5	1.2	180-1, 180-10
15	1.2	180-2, 180-11
15	2.4	180-6, 180-13; 120-5, 120-8
20	2.4	180-7, 180-14
25	1.2	180-4, 180-12
30	1.2	120-9, 120-4; 120-13, 120-10
30	2.4	120-14, 120-11
40	2.4	180-9, 180-15; 120-15, 120-12

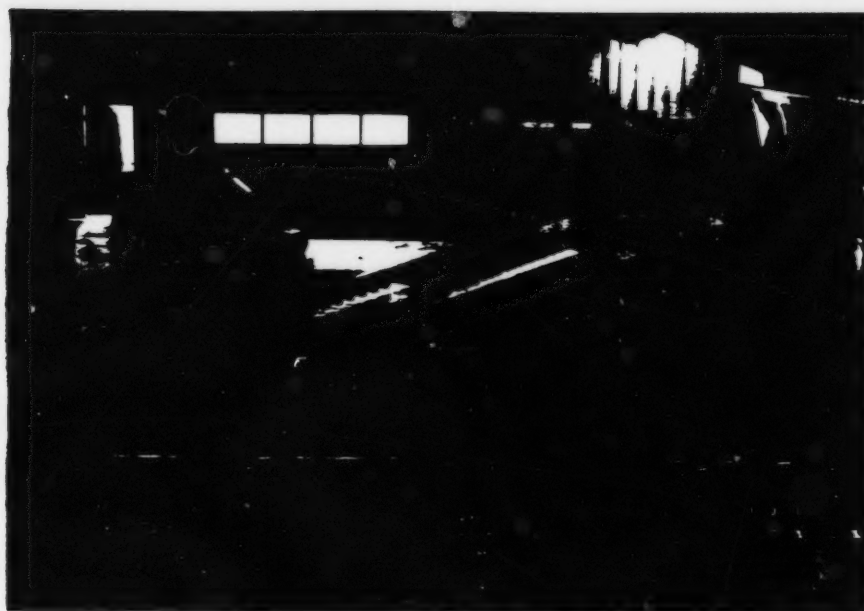
FIGURE 1



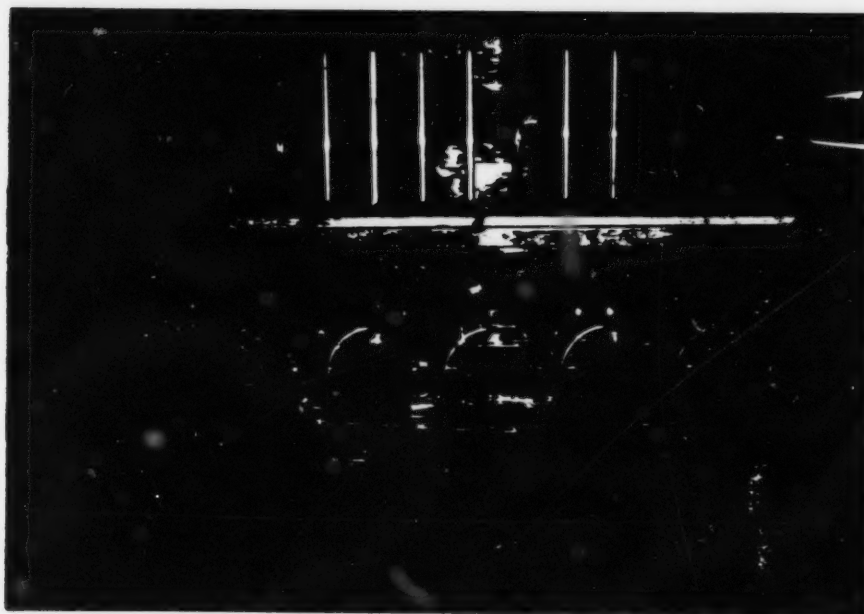
Note
Dimensions shown are
actual model units.

Scale
Model 1:100
Prototype 1:1500

MULTIPLE SYPHON GENERATORS
MODEL LAYOUT



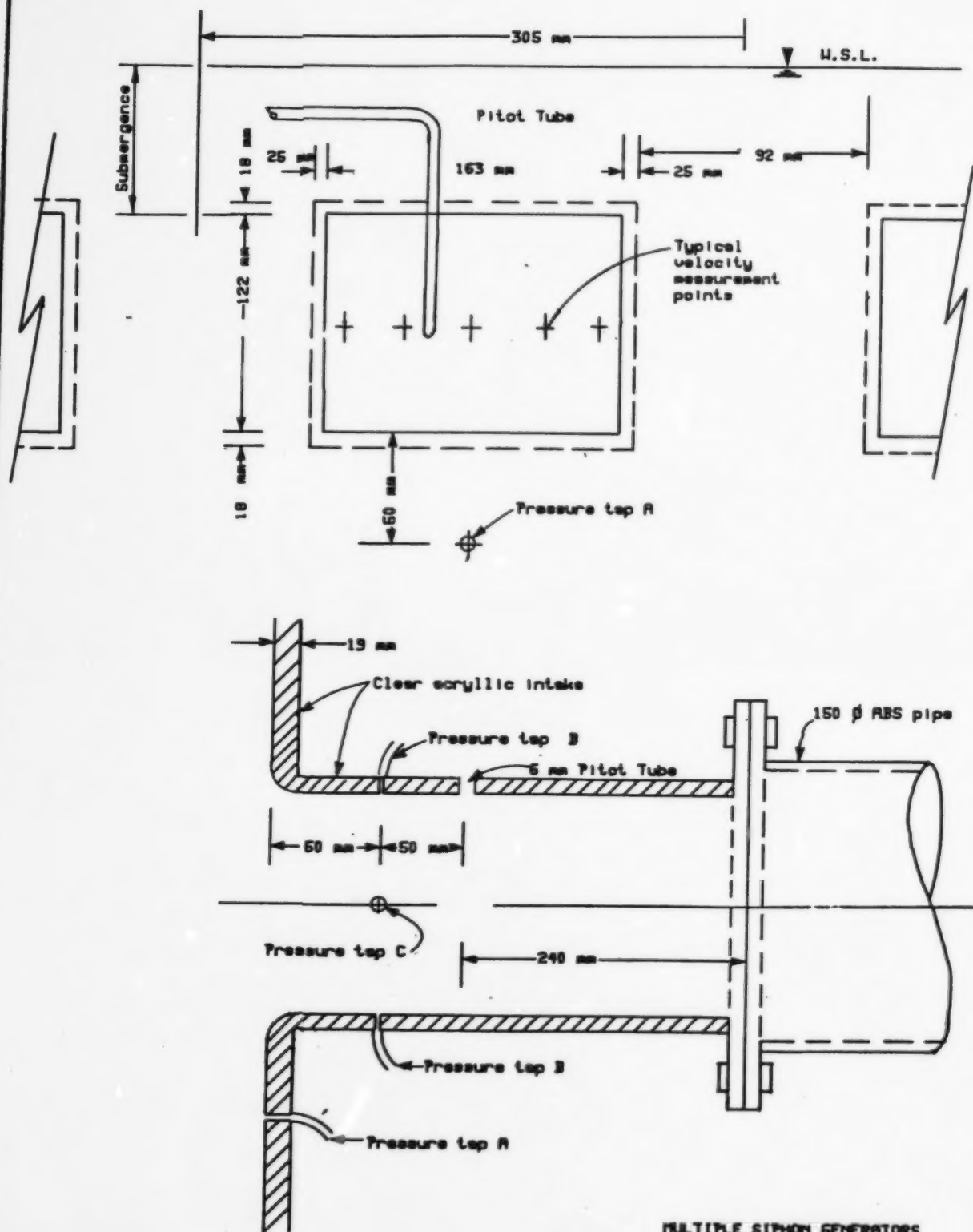
A. Model overview (180° approach channel)



B. View of intake assembly

VIEW OF MODEL

FIGURE 3



Note: Dimensions are given in model units

MULTIPLE SIPHON GENERATORS
INSTRUMENT
LOCATIONS

FIGURE 4



A. Pressure manifold and transducer assembly



B. Directional pitot tube
INSTRUMENTATION

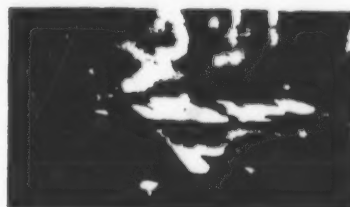
CLASS 1
Surface rotation and dimple

CLASS 2
Dimple with diffuse tail

CLASS 3
Well-defined tail

CLASS 4
Intermittent air bubbles

CLASS 5
Steady air core

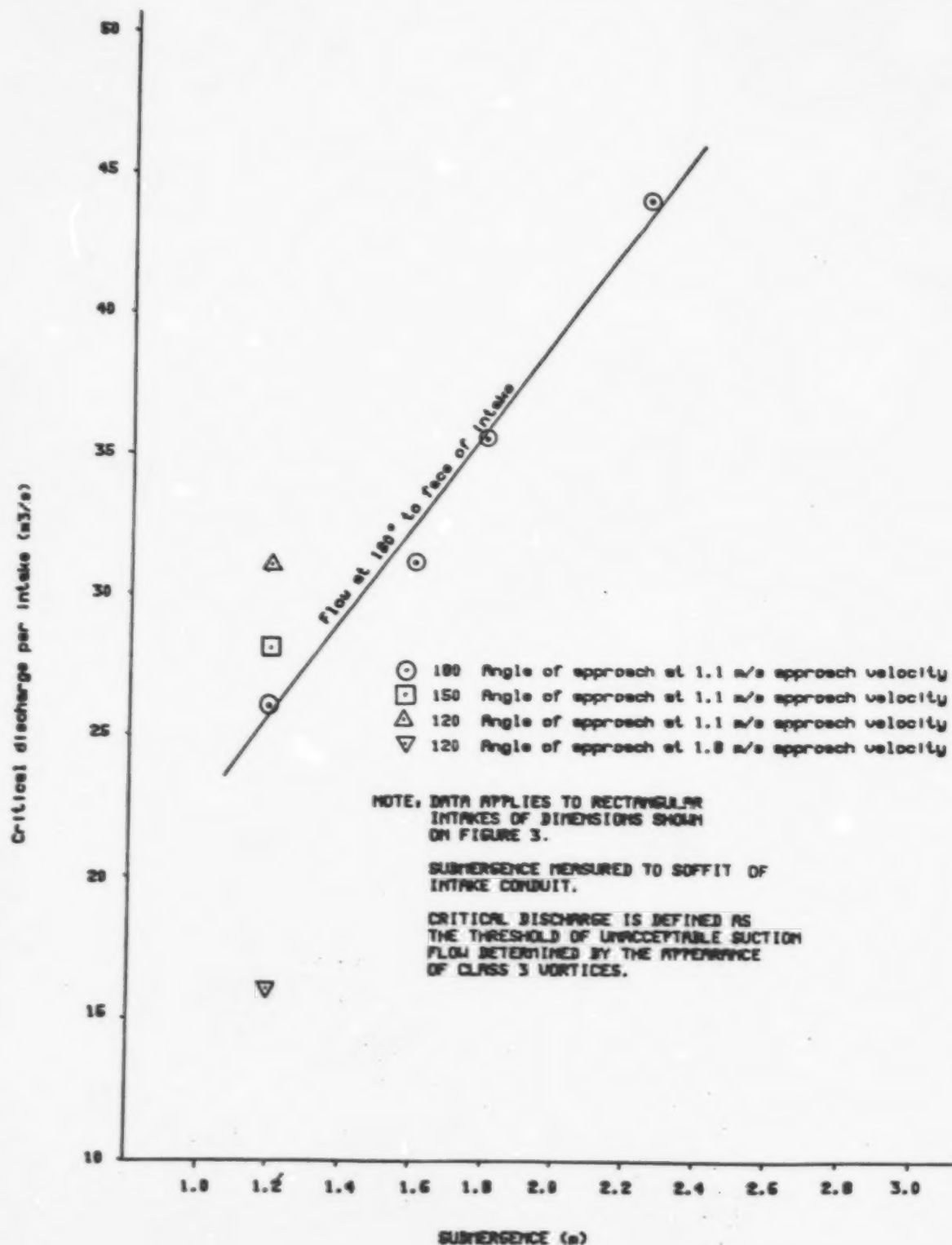


MULTIPLE SIPHON GENERATORS
VORTEX CLASSIFICATION

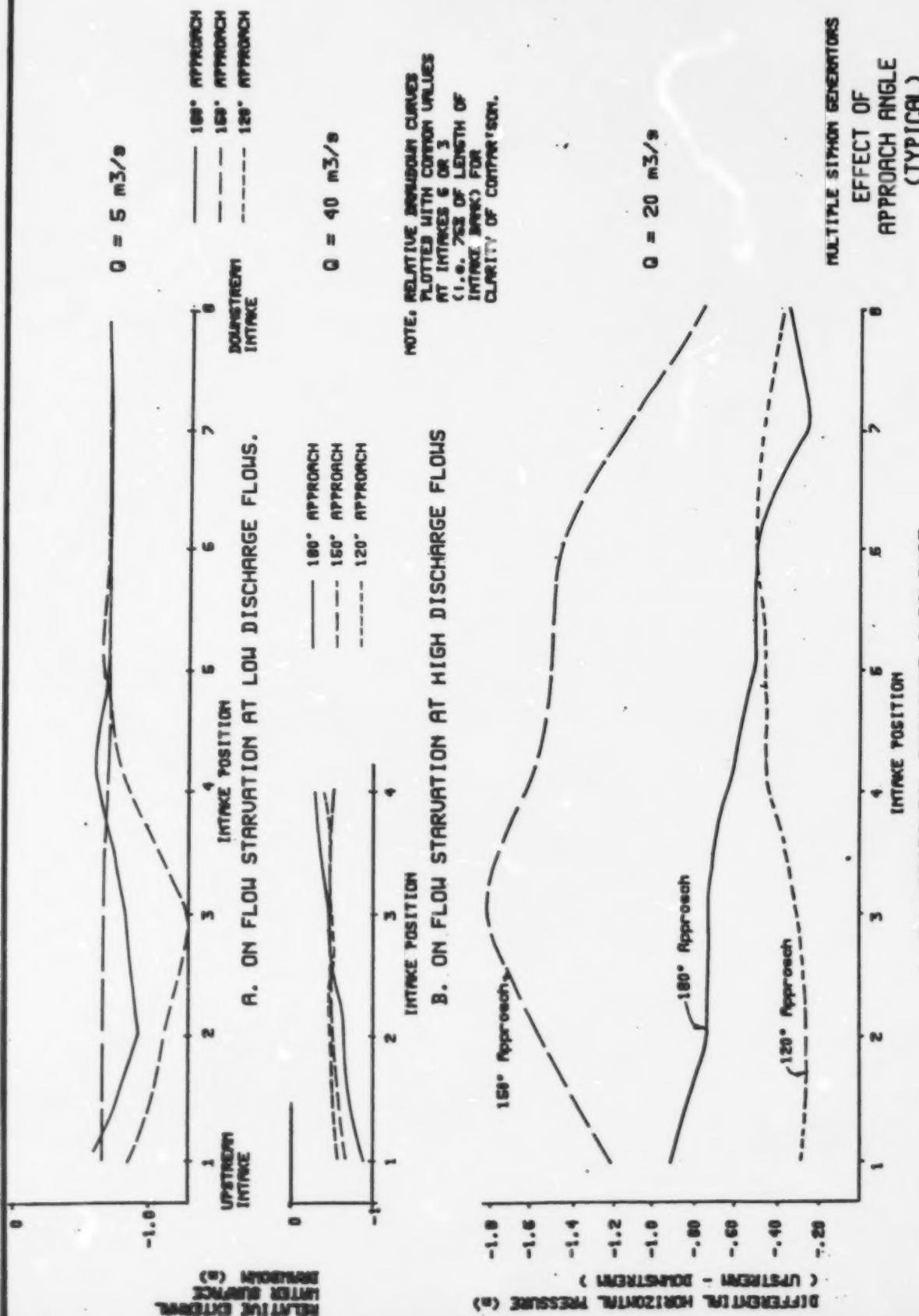
FIGURE 6

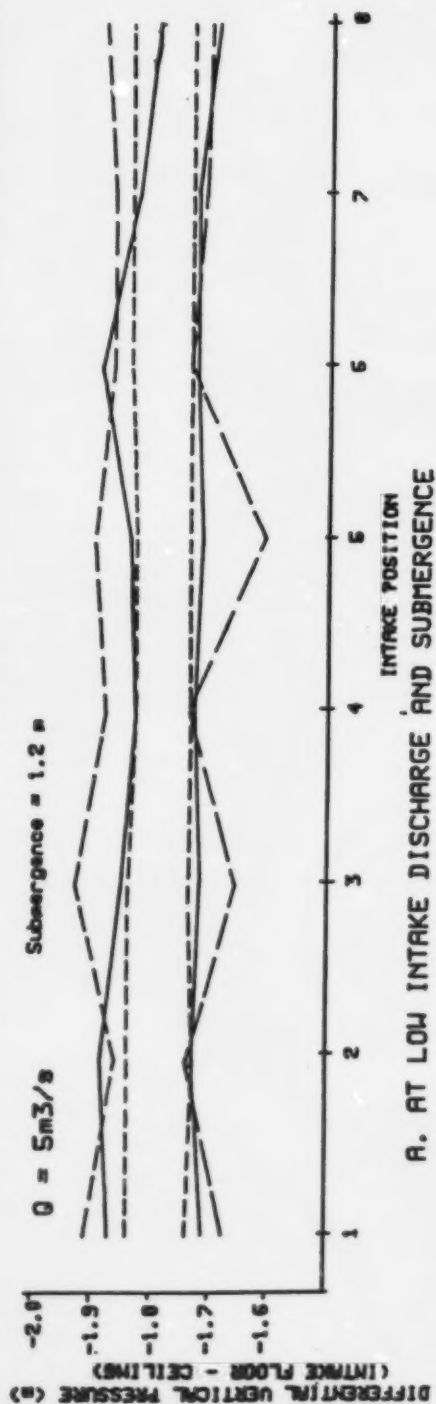


Typical brush chart recordings of differential and
hydrostatic pressures



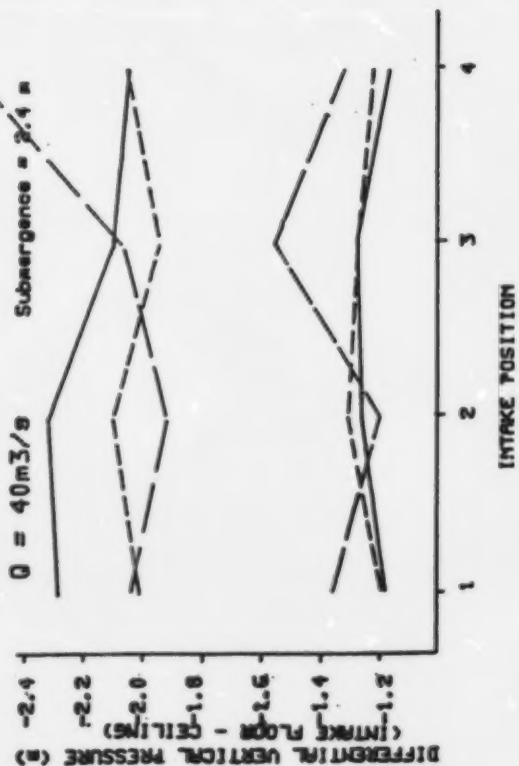
MULTIPLE SYTHON GENERATORS
EFFECT OF SUBMERGENCE
ON CRITICAL FLOWS



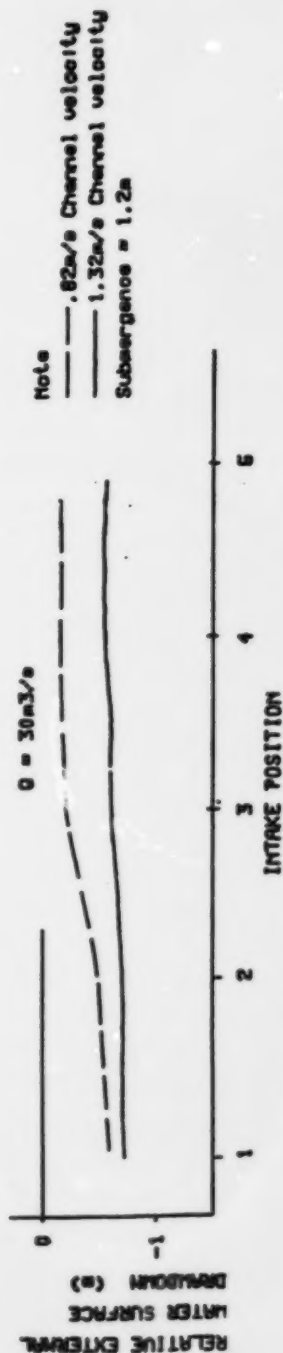


Note

- 180° Approach angle
- - - 150° Approach angle
- · - 120° Approach angle



MULTIPLE SIMON GENERATORS
EFFECT OF APPROACH ANGLE
ON
VERTICAL PRESSURE IMBALANCE
AT EACH INTAKE



A. 120° APPROACH ANGLE

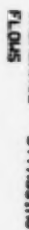


B. 150° APPROACH ANGLE

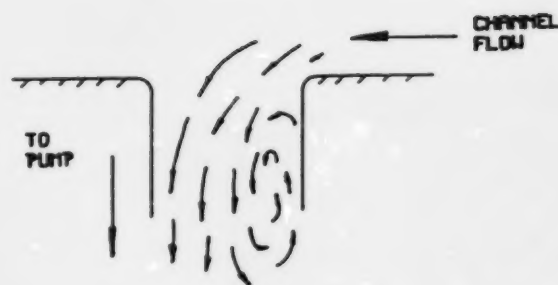
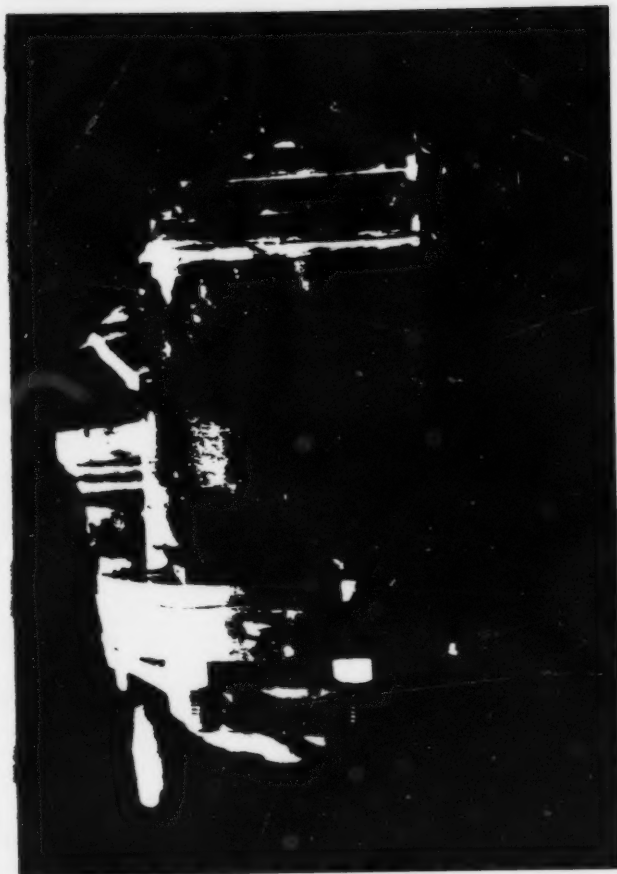


C. 180° APPROACH ANGLE

MULTIPLE SIPHON GENERATORS
 EFFECT OF APPROACH VELOCITY
 ON FLOW STARVATION
 ALONG LINE OF INTAKES



EFFECT OF APPROACH VELOCITY ON PRESSURE IMBALANCE AT EACH INTRUDE

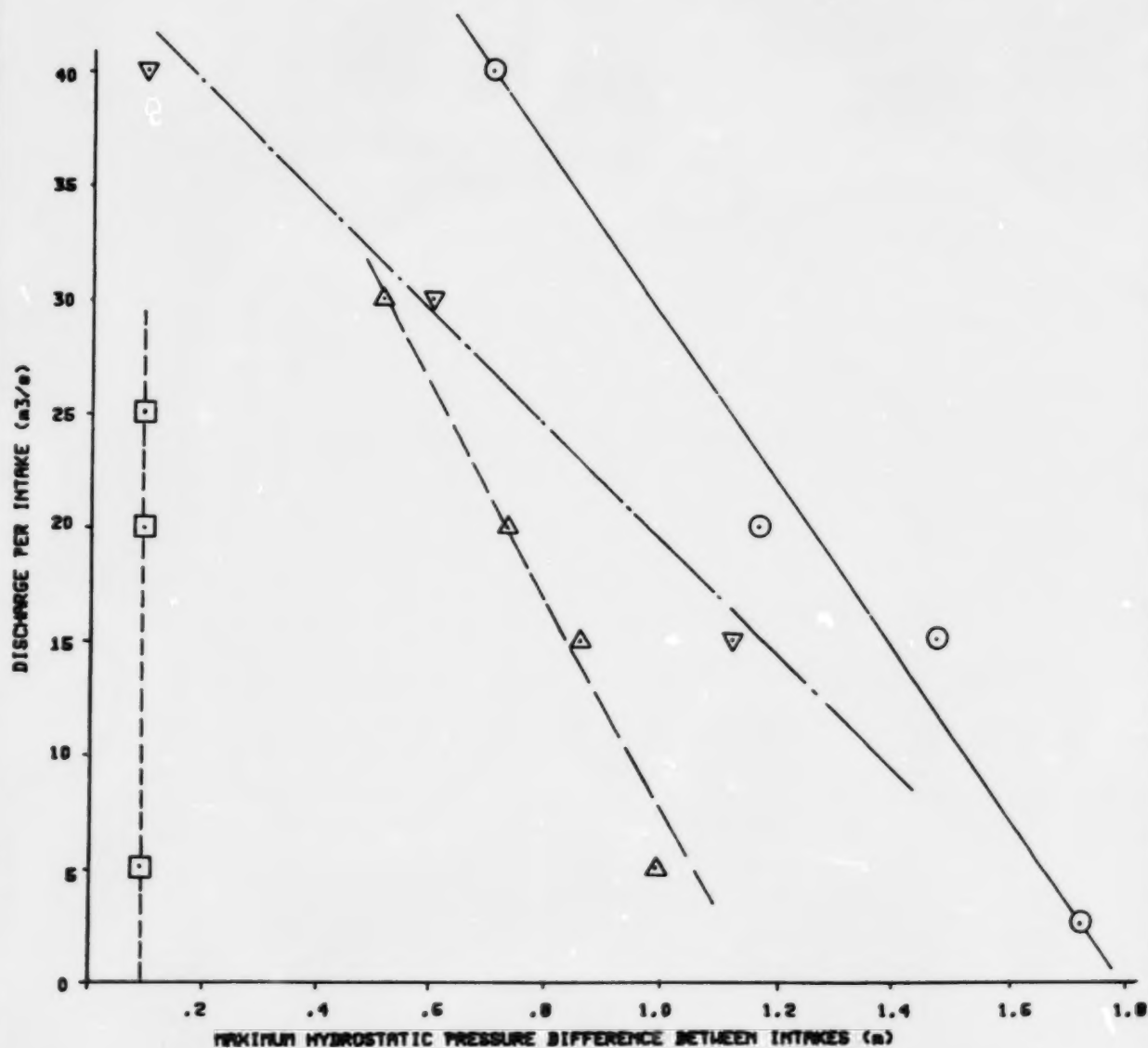


Plan View of Intake

Plan view of permanganate dye introduced downstream of entrance to Intake No. 1 to show recirculation zone on right hand side of photograph. The main flow stream is from right to left past the intake face at the top of the photograph.

INTAKE RECIRCULATION ZONE

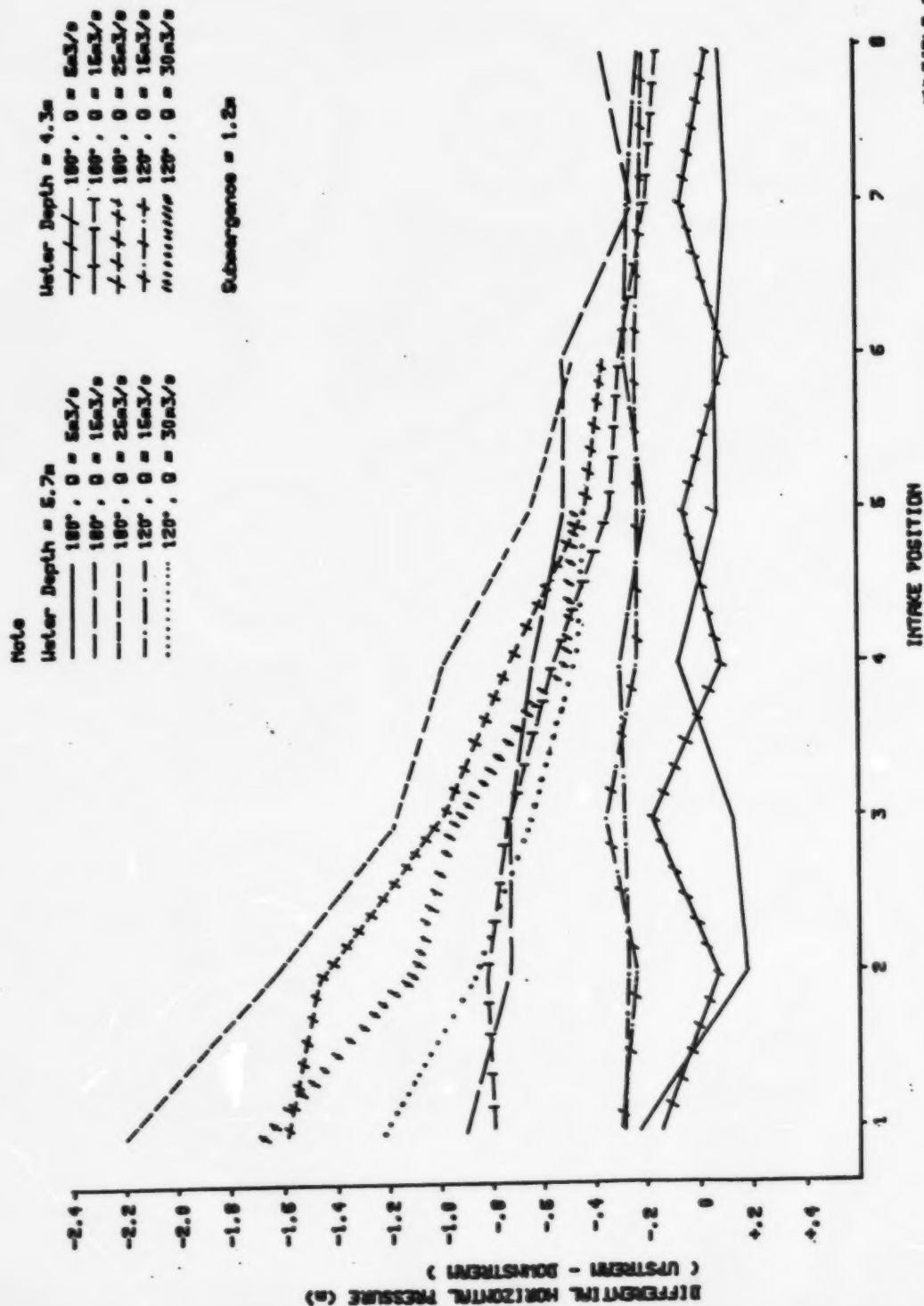
FIGURE 13



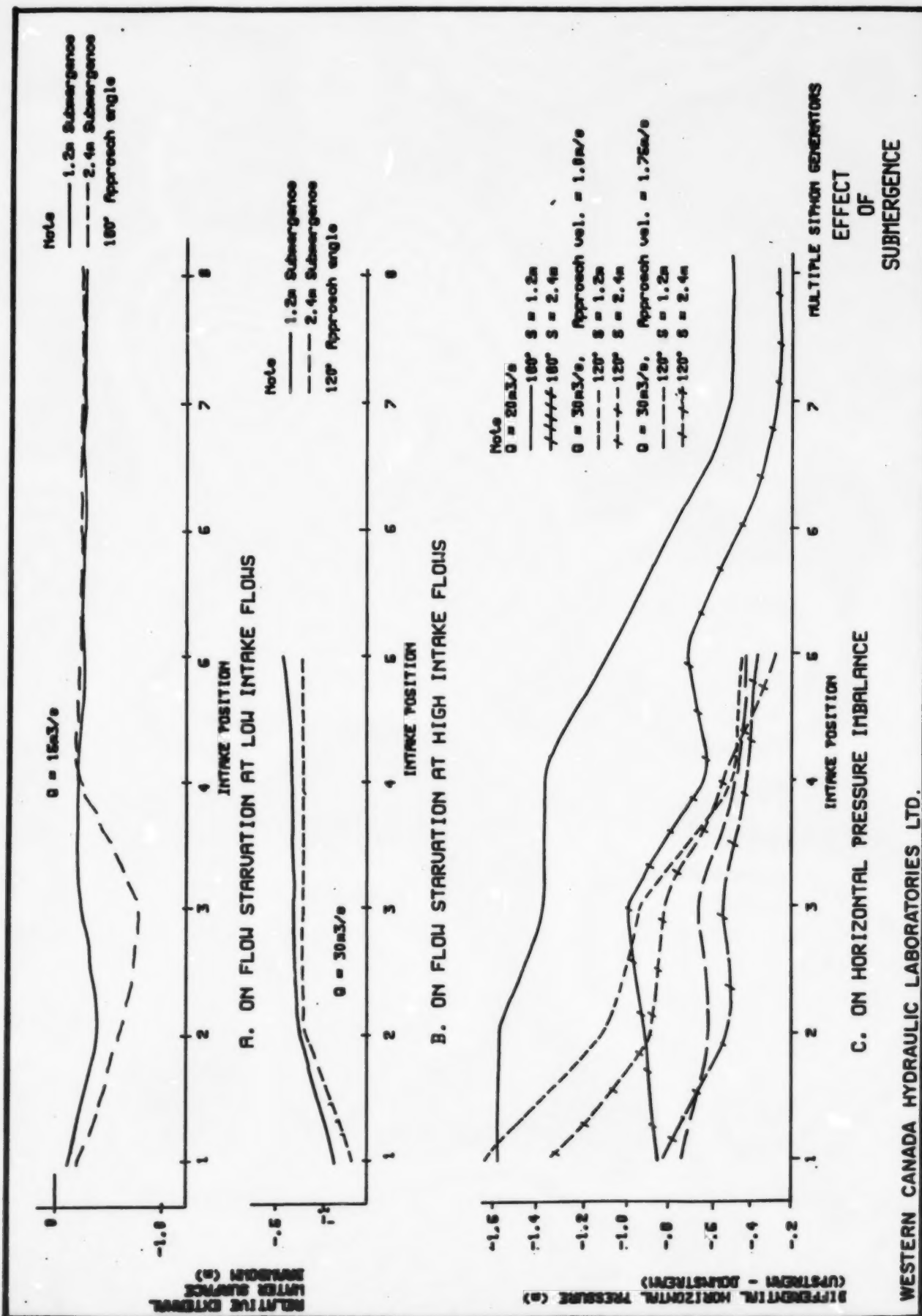
Note

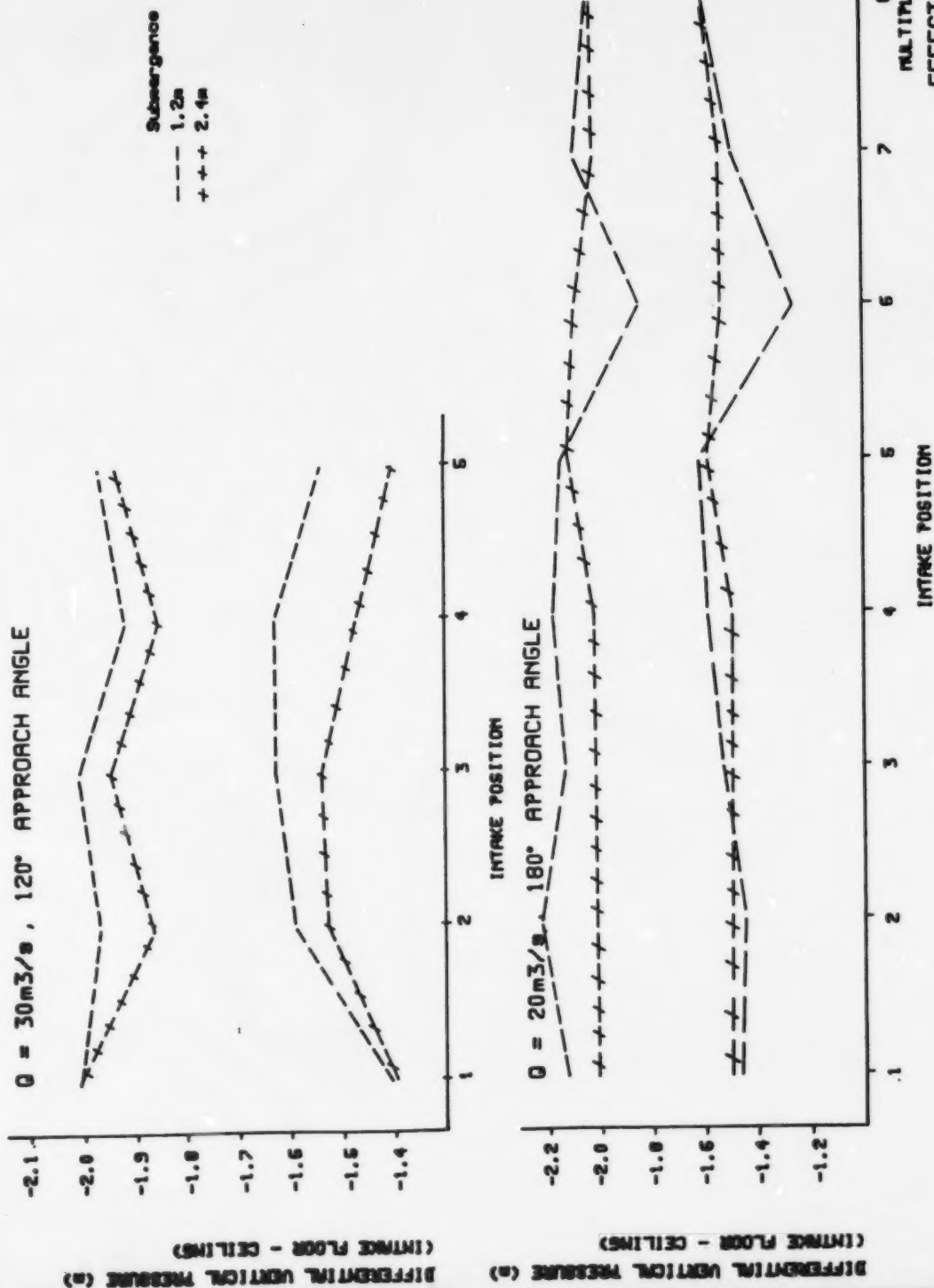
- 180° Approach, S = 2.4m
- △— 120° Approach, S = 1.2m
- ▽— 120° Approach, S = 2.4m
- 150° Approach, S = 1.2m

MULTIPLE SIPHON GENERATORS
EFFECT OF DISCHARGE
ON FLOW STARVATION



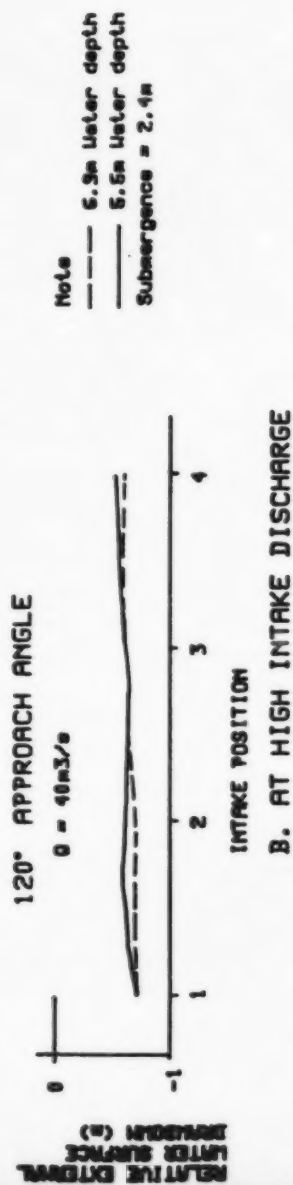
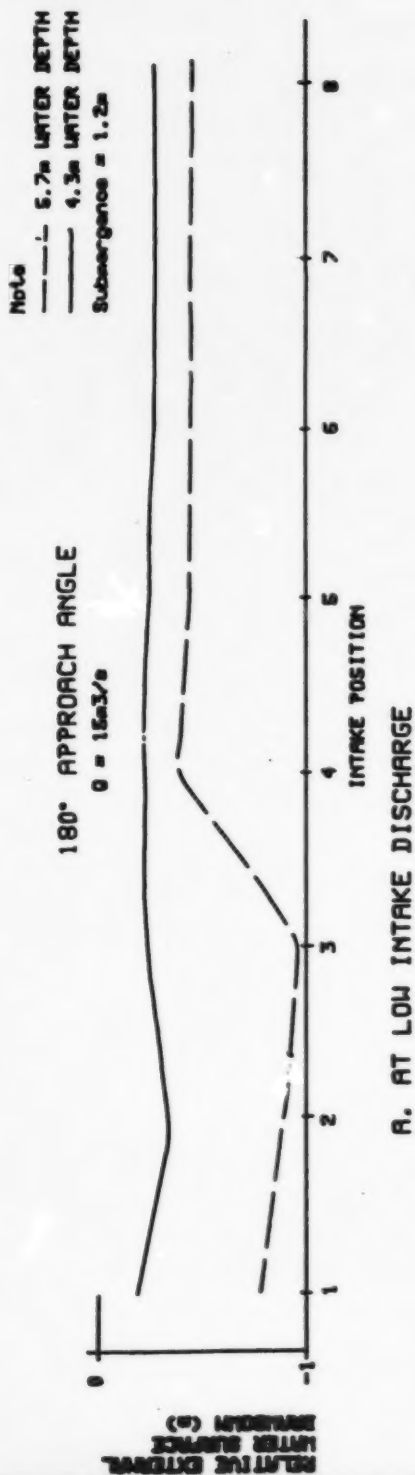
MULTIPLE SIPHON GENERATORS
EFFECT BOTTOM CLEARANCE
ON VARIATIONS IN HORIZONTAL
PRESSURE IMBALANCE

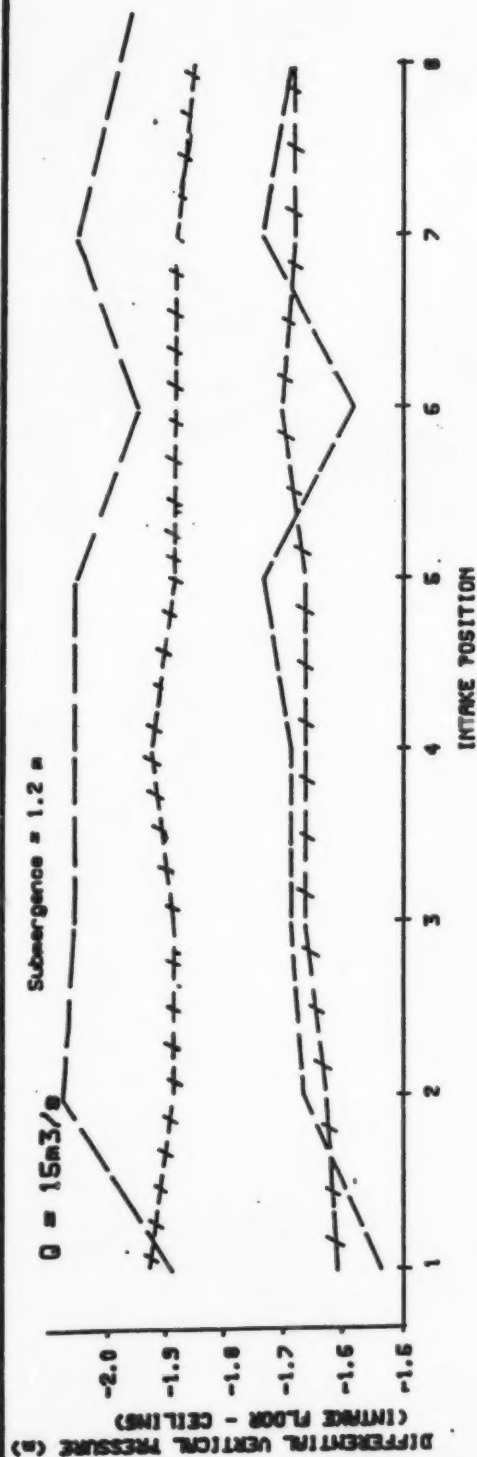




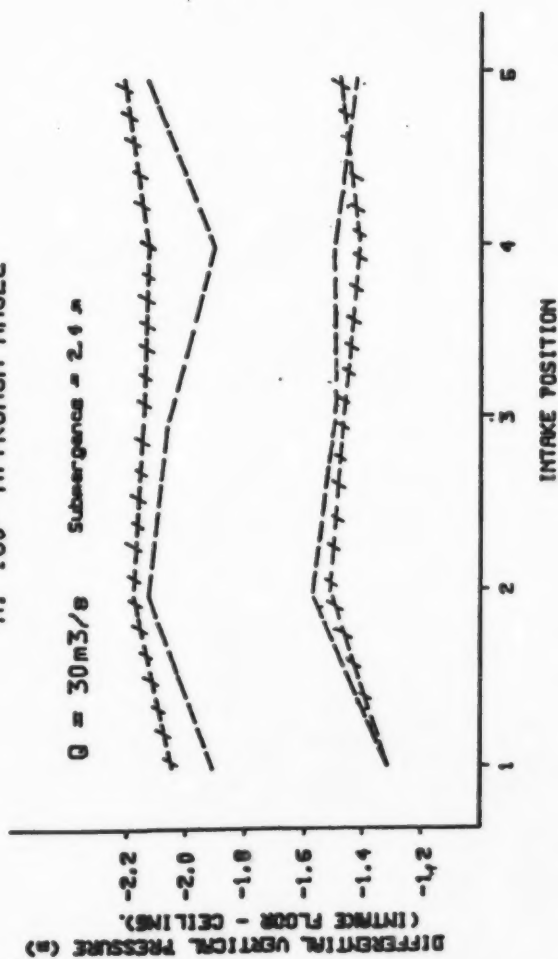
MULTIPLE SIPHON GENERATORS
EFFECT OF SUBMERGENCE
ON
VERTICAL PRESSURE IMBALANCE

MULTIPLE SIPHON GENERATORS
EFFECT OF BOTTOM CLEARANCE
ON
FLOW STARVATION





A. 180° APPROACH ANGLE



B. 120° APPROACH ANGLE

MULTIPLE SIPHON GENERATORS
EFFECT OF BOTTOM
CLEARANCE ON
VERTICAL PRESSURE IMBALANCE

APPENDIX A

Test Results: Differential and Hydrostatic Pressures

MULTIPLE SIPHON GENERATORS
TEST RESULTS : DIFFERENTIAL AND HYDROSTATIC PRESSURES

NOTE: Differential horizontal pressures are differences between downstream and upstream wall pressures
 Differential vertical pressures are differences between intake floor and ceiling pressures

TEST NUMBER	: 180-1	DATE	: 24/11/87	NO OF OPERATING INTAKES	: 8
FLOW PER INTAKE	: 5 cumecs	DEPTH OF SUBMERGENCE	: 1.2 m	VORTEX CONDITION	: 0
ANGLE OF APPROACH	: 180 deg	WATER DEPTH	: 5.7 m	NOTES	:
CHANNEL VELOCITY	: 0.2 m/s	CHANNEL WIDTH	: 32 m		

INTAKE NO.	FLOW (cumecs)	HYDROSTATIC PRESSURE (m)	DIFFERENTIAL HORIZONTAL PRESSURES				DIFFERENTIAL VERTICAL PRESSURES				
			AVERAGE (m)	PRESSURE VARIATIONS			PRESSURE VARIATIONS				
				TYPICAL MAXIMUM (m)	PERIOD (sec)	EXTREME MAXIMUM (m)	TYPICAL L>U (m)	MAXIMUM L<U (m)	PERIOD (sec)	EXTREME L>U (m)	MAXIMUM L<U (m)
1	4.84	3.25	-0.08	-0.23	0.77	-0.25	0.29	0.03	0.77	0.30	0.00
2	4.93	2.86	0.09	0.18	0.39	0.19	0.32	0.03	0.39	0.30	0.00
3	4.93	2.73	0.02	0.14	0.39	0.18	0.12	-0.06	0.31	0.10	-0.09
4	4.69	3.68	0.02	-0.09	0.39	-0.10	0.09	-0.05	0.31	0.09	-0.09
5	4.93	3.76	0.03	-0.08	0.39	0.08	0.10	-0.04	0.31	0.07	-0.08
6	4.69	3.68	0.02	0.08	0.39	0.08	0.20	0.04	0.31	0.21	0.00
7	4.84	3.68	0.06	0.11	0.39	0.12	0.08	-0.08	0.31	0.07	-0.13
8	4.93	3.68	0.03	0.09	0.39	0.12	0.06	-0.07	0.31	0.10	-0.11

TEST NUMBER	: 180-2	DATE	: 24/11/87	NO OF OPERATING INTAKES	: 8
FLOW PER INTAKE	: 15 cumecs	DEPTH OF SUBMERGENCE	: 1.2 m	VORTEX CONDITION	: 1
ANGLE OF APPROACH	: 180 deg	WATER DEPTH	: 5.7 m	NOTES	: periodic reverse waves
CHANNEL VELOCITY	: 0.66 m/s	CHANNEL WIDTH	: 32 m		class 3 at intakes 7 & 8

INTAKE NO.	FLOW (cumecs)	HYDROSTATIC PRESSURE (m)	DIFFERENTIAL HORIZONTAL PRESSURES				DIFFERENTIAL VERTICAL PRESSURES				
			AVERAGE (m)	PRESSURE VARIATIONS			PRESSURE VARIATIONS				
				TYPICAL MAXIMUM (m)	PERIOD (sec)	EXTREME MAXIMUM (m)	TYPICAL L>U (m)	MAXIMUM L<U (m)	PERIOD (sec)	EXTREME L>U (m)	MAXIMUM L<U (m)
1	15.05	3.30	-0.58	-0.90	1.94	-1.05	0.29	-0.06	1.16	0.33	-0.10
2	15.05	3.08	-0.45	-0.73	2.32	-1.01	0.16	-0.26	1.94	0.22	-0.29
3	15.05	2.99	-0.47	-0.73	2.32	-0.79	0.14	-0.23	1.16	0.20	-0.27
4	15.05	3.98	-0.41	-0.64	2.32	-0.82	0.14	-0.23	1.16	0.16	-0.31
5	15.05	3.90	-0.32	-0.52	1.55	-0.56	0.09	-0.23	1.16	0.12	-0.27
6	15.05	3.90	-0.28	-0.52	1.16	-0.56	0.24	-0.12	1.01	0.24	-0.23
7	15.05	3.85	0.11	0.26	0.46	0.26	0.09	-0.23	0.46	0.12	-0.25
8	15.05	3.85	-0.15	-0.37	0.46	-0.43	0.14	-0.16	0.46	0.16	-0.23

TEST NUMBER	: 180-3	DATE	: 25/11/87	NO OF OPERATING INTAKES	: 8
FLOW PER INTAKE	: 20 cumecs	DEPTH OF SUBMERGENCE	: 1.2 m	VORTEX CONDITION	: 1
ANGLE OF APPROACH	: 180 deg	WATER DEPTH	: 5.7 m	NOTES	: small class 3 vortex
CHANNEL VELOCITY	: 0.88 m/s	CHANNEL WIDTH	: 32 m		at intake 8

INTAKE NO.	FLOW (cumecs)	HYDROSTATIC PRESSURE (m)	DIFFERENTIAL HORIZONTAL PRESSURES				DIFFERENTIAL VERTICAL PRESSURES				
			AVERAGE (m)	PRESSURE VARIATIONS			PRESSURE VARIATIONS				
				TYPICAL MAXIMUM (m)	PERIOD (sec)	EXTREME MAXIMUM (m)	TYPICAL L>U (m)	MAXIMUM L<U (m)	PERIOD (sec)	EXTREME L>U (m)	MAXIMUM L<U (m)
1	19.99	3.49	-0.95	-1.60	1.94	-1.69	0.35	-0.29	1.16	0.42	-0.40
2	19.99	3.31	-0.95	-1.60	2.32	-1.69	0.38	-0.38	1.01	0.42	-0.49
3	19.99	3.10	-0.93	-1.39	2.32	-1.45	0.29	-0.29	1.16	0.35	-0.36
4	19.99	4.01	-0.84	-1.39	2.32	-1.56	0.25	-0.34	1.16	0.31	-0.38
5	19.99	4.09	-0.39	-0.78	2.32	-0.82	0.20	-0.32	1.01	0.27	-0.40
6	19.99	4.14	-0.43	-0.78	2.32	-0.91	0.55	-0.01	1.01	0.59	-0.16
7	19.99	4.14	-0.26	-0.52	2.32	-0.91	0.33	-0.25	1.32	0.44	-0.40
8	19.99	4.18	-0.30	-0.52	1.55	-0.58	0.25	-0.21	1.32	0.38	-0.36

MULTIPLE SIPHON GENERATORS
TEST RESULTS : DIFFERENTIAL AND HYDROSTATIC PRESSURES

TEST NUMBER : 180-4
FLOW PER INTAKE : 25 cumecs
ANGLE OF APPROACH : 180 deg
CHANNEL VELOCITY : 0.82 m/s

DATE : 25/11/87
DEPTH OF SUBMERGENCE : 1.2 m
WATER DEPTH : 5.7 m
CHANNEL WIDTH : 32 m

NO OF OPERATING INTAKES : 6
VORTEX CONDITION : 1
NOTES : random bubbles intake 1
class 3 @ intake 6

INTAKE NO.	FLOW (cumecs)	HYDROSTATIC PRESSURE (m)	DIFFERENTIAL HORIZONTAL PRESSURES				DIFFERENTIAL VERTICAL PRESSURES				
			AVERAGE (m)	PRESSURE VARIATIONS			PRESSURE VARIATIONS				
				TYPICAL MAXIMUM (m)	PERIOD (sec)	EXTREME MAXIMUM (m)	TYPICAL L>U (m)	MAXIMUM L<U (m)	PERIOD (sec)	EXTREME L>U (m)	MAXIMUM L<U (m)
1	25.12	3.14	-1.49	-2.21	1.94	-2.25	0.42	-0.27	1.32	0.51	-0.36
2	25.12	4.09	-1.00	-1.65	2.32	-1.91	0.40	-0.40	1.16	0.44	-0.55
3	25.12	4.05	-0.63	-1.17	2.32	-1.47	0.20	-0.45	1.32	0.33	-0.66
4	25.12	4.05	-0.54	-1.00	1.94	-1.21	0.38	-0.40	1.01	0.51	-0.55
5	25.12	4.18	-0.32	-0.65	1.16	-0.87	0.25	-0.33	1.01	0.38	-0.45
6	25.12	4.09	-0.22	-0.48	1.16	0.58	0.29	-0.32	1.16	0.33	-0.45

TEST NUMBER : 180-5
FLOW PER INTAKE : 5 cumecs
ANGLE OF APPROACH : 180 deg
CHANNEL VELOCITY : 0.18 m/s

DATE : 20/11/87
DEPTH OF SUBMERGENCE : 2.4 m
WATER DEPTH : 6.9 m
CHANNEL WIDTH : 32 m

NO OF OPERATING INTAKES : 8
VORTEX CONDITION : 0
NOTES :

INTAKE NO.	FLOW (cumecs)	HYDROSTATIC PRESSURE (m)	DIFFERENTIAL HORIZONTAL PRESSURES				DIFFERENTIAL VERTICAL PRESSURES				
			AVERAGE (m)	PRESSURE VARIATIONS			PRESSURE VARIATIONS				
				TYPICAL MAXIMUM (m)	PERIOD (sec)	EXTREME MAXIMUM (m)	TYPICAL L>U (m)	MAXIMUM L<U (m)	PERIOD (sec)	EXTREME L>U (m)	MAXIMUM L<U (m)
1	4.81	3.21	-0.13	-0.24	0.19	-0.28	0.16	-0.12	0.31	-0.12	-0.14
2	4.69	4.08	-0.09	-0.15	0.27	-0.17	0.12	-0.06	0.31	-0.14	-0.10
3	4.81	4.03	-0.06	-0.11	0.23	-0.13	0.09	-0.03	0.23	0.12	-0.06
4	4.81	4.81	-0.03	-0.07	0.23	-0.09	0.07	-0.03	0.17	0.12	-0.06
5	4.81	4.77	-0.10	-0.15	0.31	-0.16	0.12	-0.03	0.15	0.16	-0.06
6	4.69	4.55	-0.06	-0.11	0.31	-0.13	0.12	-0.06	0.27	0.12	-0.06
7	4.81	4.98	-0.04	-0.09	0.27	-0.11	0.09	-0.03	0.31	0.12	-0.06
8	4.81	4.94	-0.02	-0.06	0.27	-0.09	0.09	-0.03	0.31	-1.69	-0.06

TEST NUMBER : 180-6
FLOW PER INTAKE : 15 cumecs
ANGLE OF APPROACH : 180 deg
CHANNEL VELOCITY : 0.54 m/s

DATE : 20/11/87
DEPTH OF SUBMERGENCE : 2.4 m
WATER DEPTH : 6.9 m
CHANNEL WIDTH : 32 m

NO OF OPERATING INTAKES : 8
VORTEX CONDITION : 0
NOTES :

INTAKE NO.	FLOW (cumecs)	HYDROSTATIC PRESSURE (m)	DIFFERENTIAL HORIZONTAL PRESSURES				DIFFERENTIAL VERTICAL PRESSURES				
			AVERAGE (m)	PRESSURE VARIATIONS			PRESSURE VARIATIONS				
				TYPICAL MAXIMUM (m)	PERIOD (sec)	EXTREME MAXIMUM (m)	TYPICAL L>U (m)	MAXIMUM L<U (m)	PERIOD (sec)	EXTREME L>U (m)	MAXIMUM L<U (m)
1	15.30	3.47	-0.62	-0.95	0.77	-1.06	0.25	-0.16	0.77	0.31	-0.25
2	15.27	4.16	-0.40	-0.65	0.93	-0.69	0.25	-0.19	0.93	0.29	-0.27
3	15.22	3.99	-0.22	-0.43	1.01	-0.78	0.25	-0.23	0.93	0.27	-0.27
4	15.27	4.85	-0.43	-0.65	1.01	-0.80	0.31	-0.23	0.93	0.35	-0.29
5	15.08	4.68	-0.17	-0.39	0.93	-0.43	0.20	-0.21	0.93	0.25	-0.25
6	15.30	4.51	-0.24	-0.39	1.08	-0.45	0.29	-0.31	0.93	0.35	-0.34
7	15.08	5.02	-0.04	-0.22	0.93	-0.26	0.20	-0.16	0.77	0.25	-0.19
8	14.85	4.94	-0.04	-0.26	0.77	-0.38	0.25	-0.21	1.08	0.40	-0.27

MULTIPLE SIPHON GENERATORS
TEST RESULTS : DIFFERENTIAL AND HYDROSTATIC PRESSURES

TEST NUMBER : 180-7
FLOW PER INTAKE : 20 cumecs
ANGLE OF APPROACH : 180 deg
CHANNEL VELOCITY : 0.72 m/s

DATE : 23/11/87
DEPTH OF SUBMERGENCE : 2.4 m
WATER DEPTH : 6.9 m
CHANNEL WIDTH : 32 m

NO OF OPERATING INTAKES : 8
VORTEX CONDITION : 0
NOTES : recirculation in channel
occasional class 3 @
intake 8

INTAKE NO.	FLOW (cumecs)	HYDROSTATIC PRESSURE (m)	DIFFERENTIAL HORIZONTAL PRESSURES				DIFFERENTIAL VERTICAL PRESSURES				
			AVERAGE (m)	PRESSURE VARIATIONS			PRESSURE VARIATIONS				
				TYPICAL MAXIMUM (m)	PERIOD (sec)	EXTREME MAXIMUM (m)	TYPICAL L>U (m)	MAXIMUM L<U (m)	PERIOD (sec)	EXTREME L>U (m)	MAXIMUM L<U (m)
1	19.69	4.11	-0.56	-0.86	0.77	-1.01	0.33	-0.19	0.77	0.37	-0.27
2	19.99	4.06	-0.60	-0.92	0.77	-0.95	0.33	-0.19	0.77	0.37	-0.23
3	19.69	3.85	-0.69	-0.99	0.77	-1.12	0.33	-0.19	0.77	0.37	-0.27
4	19.69	4.79	-0.32	-0.65	0.77	-0.86	0.33	-0.19	0.77	0.40	-0.25
5	19.99	4.84	-0.43	-0.73	0.93	-0.80	0.25	-0.29	0.93	0.29	-0.36
6	19.99	4.92	-0.24	-0.47	0.93	-0.54	0.29	-0.27	0.93	0.37	-0.29
7	19.99	4.97	-0.06	-0.30	0.93	-0.52	0.29	-0.19	0.93	0.42	-0.23
8	19.99	5.01	-0.09	-0.30	0.93	-0.47	0.25	-0.19	0.93	0.33	-0.27

TEST NUMBER : 180-8
FLOW PER INTAKE : 30 cumecs
ANGLE OF APPROACH : 180 deg
CHANNEL VELOCITY : 0.68 m/s

DATE : 23/11/87
DEPTH OF SUBMERGENCE : 2.4 m
WATER DEPTH : 6.9 m
CHANNEL WIDTH : 32 m

NO OF OPERATING INTAKES : 5
VORTEX CONDITION : 0
NOTES : recirculation in channel
small class 3 @ 4,5
not reaching soffit

INTAKE NO.	FLOW (cumecs)	HYDROSTATIC PRESSURE (m)	DIFFERENTIAL HORIZONTAL PRESSURES				DIFFERENTIAL VERTICAL PRESSURES				
			AVERAGE (m)	PRESSURE VARIATIONS			PRESSURE VARIATIONS				
				TYPICAL MAXIMUM (m)	PERIOD (sec)	EXTREME MAXIMUM (m)	TYPICAL L>U (m)	MAXIMUM L<U (m)	PERIOD (sec)	EXTREME L>U (m)	MAXIMUM L<U (m)
1	30.20	4.28	-1.12	-1.63	0.77	-1.81	0.52	0.42	0.77	0.68	-0.40
2	30.20	4.19	-0.77	-1.29	0.93	-1.55	0.55	-0.49	0.93	0.65	-0.70
3	30.20	4.11	-0.60	-1.20	0.93	-1.46	0.46	-0.40	0.77	0.59	-0.53
4	30.20	4.19	-0.25	-0.69	0.93	-1.46	0.52	-0.46	0.93	0.59	-0.53
5	30.20	4.19	-0.39	-0.95	1.01	-1.16	0.63	-0.44	1.01	0.93	-0.79

TEST NUMBER : 180-9
FLOW PER INTAKE : 40 cumecs
ANGLE OF APPROACH : 180 deg
CHANNEL VELOCITY : 0.72 m/s

DATE : 24/11/87
DEPTH OF SUBMERGENCE : 2.4 m
WATER DEPTH : 6.9 m
CHANNEL WIDTH : 32 m

NO OF OPERATING INTAKES : 4
VORTEX CONDITION : 1
NOTES : class 3 @ intake 4
moving downstream

INTAKE NO.	FLOW (cumecs)	HYDROSTATIC PRESSURE (m)	DIFFERENTIAL HORIZONTAL PRESSURES				DIFFERENTIAL VERTICAL PRESSURES				
			AVERAGE (m)	PRESSURE VARIATIONS			PRESSURE VARIATIONS				
				TYPICAL MAXIMUM (m)	PERIOD (sec)	EXTREME MAXIMUM (m)	TYPICAL L>U (m)	MAXIMUM L<U (m)	PERIOD (sec)	EXTREME L>U (m)	MAXIMUM L<U (m)
1	39.60	3.98	-1.25	-2.23	1.70	-2.32	0.65	-0.46	1.08	0.72	-0.61
2	39.60	3.81	-0.99	-1.63	0.93	-1.89	0.50	-0.53	0.93	0.74	-0.79
3	39.60	3.68	-0.43	-1.07	1.08	-1.37	0.50	-0.51	1.39	0.59	-0.66
4	39.60	4.37	0.39	1.20	1.24	1.68	0.76	-0.74	1.08	1.08	-1.13

MULTIPLE SIPHON GENERATORS
TEST RESULTS : DIFFERENTIAL AND HYDROSTATIC PRESSURES

TEST NUMBER : 180-10
 FLOW PER INTAKE : 5 cumecs
 ANGLE OF APPROACH : 180 deg
 CHANNEL VELOCITY : 0.29 m/s

DATE : 26/11/87
 DEPTH OF SUBMERGENCE : 1.2 m
 WATER DEPTH : 4.3 m
 CHANNEL WIDTH : 32 m

NO OF OPERATING INTAKES : 8
 VORTEX CONDITION : 0
 NOTES :

INTAKE NO.	FLOW (cumecs)	HYDROSTATIC PRESSURE (m)	DIFFERENTIAL HORIZONTAL PRESSURES				DIFFERENTIAL VERTICAL PRESSURES				
			AVERAGE (m)	PRESSURE VARIATIONS			PRESSURE VARIATIONS				
				TYPICAL MAXIMUM (m)	PERIOD (sec)	EXTREME MAXIMUM (m)	TYPICAL L>U (m)	MAXIMUM L<U (m)	PERIOD (sec)	EXTREME L>U (m)	MAXIMUM L<U (m)
				(m)	(sec)	(m)	(m)	(m)	(sec)	(m)	(m)
1	5.06	4.43	-0.01	-0.15	0.39	-0.17	0.12	-0.04	0.31	0.13	-0.05
2	4.93	3.91	0.00	0.09	0.31	-0.10	0.10	-0.05	0.31	0.12	-0.06
3	4.81	3.74	-0.01	-0.09	0.39	0.13	0.11	-0.02	0.39	0.12	-0.03
4	4.93	4.38	0.03	0.09	0.39	0.10	0.10	0.00	0.39	0.11	-0.02
5	5.06	4.21	-0.02	-0.07	0.39	-0.09	0.11	-0.01	0.31	0.13	-0.03
6	4.81	4.21	0.04	0.10	0.39	0.12	0.10	-0.06	0.39	0.12	-0.09
7	4.93	4.21	-0.01	-0.06	0.31	-0.09	0.10	0.00	0.31	0.11	-0.02
8	4.81	4.21	-0.01	0.03	0.39	0.07	0.13	0.03	0.23	0.16	0.01

TEST NUMBER : 180-11
 FLOW PER INTAKE : 15 cumecs
 ANGLE OF APPROACH : 180 deg
 CHANNEL VELOCITY : 0.87 m/s

DATE : 26/11/87
 DEPTH OF SUBMERGENCE : 1.2 m
 WATER DEPTH : 4.3 m
 CHANNEL WIDTH : 32 m

NO OF OPERATING INTAKES : 8
 VORTEX CONDITION : 1
 NOTES : small class 3 @ 7,8
 not entering intakes
 no channel recirculation

INTAKE NO.	FLOW (cumecs)	HYDROSTATIC PRESSURE (m)	DIFFERENTIAL HORIZONTAL PRESSURES				DIFFERENTIAL VERTICAL PRESSURES				
			AVERAGE (m)	PRESSURE VARIATIONS			PRESSURE VARIATIONS				
				TYPICAL MAXIMUM (m)	PERIOD (sec)	EXTREME MAXIMUM (m)	TYPICAL L>U (m)	MAXIMUM L<U (m)	PERIOD (sec)	EXTREME L>U (m)	MAXIMUM L<U (m)
				(m)	(sec)	(m)	(m)	(m)	(sec)	(m)	(m)
1	15.05	4.38	-0.47	-0.80	1.08	-0.91	0.22	-0.10	0.24	0.34	-0.14
2	15.05	3.74	-0.54	-0.82	2.32	-0.93	0.20	-0.06	0.28	0.27	-0.12
3	15.05	3.56	-0.45	-0.73	0.93	-0.86	0.16	-0.06	0.30	0.20	-0.10
4	15.05	4.25	-0.34	-0.56	1.16	-0.65	0.16	-0.10	0.30	0.20	-0.14
5	15.05	4.21	-0.17	-0.34	1.16	-0.54	0.16	-0.06	0.30	0.20	-0.10
6	15.05	4.17	-0.17	-0.30	1.16	-0.34	0.12	-0.06	0.24	0.14	-0.10
7	15.05	4.17	-0.04	-0.22	1.08	-0.30	0.14	-0.06	0.26	0.14	-0.08
8	15.05	4.17	0.02	0.15	1.16	0.17	0.14	-0.03	0.30	0.16	-0.08

TEST NUMBER : 180-12
 FLOW PER INTAKE : 25 cumecs
 ANGLE OF APPROACH : 180 deg
 CHANNEL VELOCITY : 1.09 m/s

DATE : 26/11/87
 DEPTH OF SUBMERGENCE : 1.2 m
 WATER DEPTH : 4.2 m
 CHANNEL WIDTH : 32 m

NO OF OPERATING INTAKES : 6
 VORTEX CONDITION : 1
 NOTES : class 4 @ intake 1

INTAKE NO.	FLOW (cumecs)	HYDROSTATIC PRESSURE (m)	DIFFERENTIAL HORIZONTAL PRESSURES				DIFFERENTIAL VERTICAL PRESSURES				
			AVERAGE (m)	PRESSURE VARIATIONS			PRESSURE VARIATIONS				
				TYPICAL MAXIMUM (m)	PERIOD (sec)	EXTREME MAXIMUM (m)	TYPICAL L>U (m)	MAXIMUM L<U (m)	PERIOD (sec)	EXTREME L>U (m)	MAXIMUM L<U (m)
				(m)	(sec)	(m)	(m)	(m)	(sec)	(m)	(m)
1	24.67	3.26	-1.12	-1.59	1.24	-1.94	0.46	-0.40	1.24	0.63	-0.70
2	24.92	4.08	-0.97	-1.47	2.17	-1.64	0.25	-0.27	1.39	0.33	-0.40
3	24.67	3.95	-0.67	-0.99	2.63	-1.16	0.18	-0.25	1.24	0.27	-0.31
4	24.58	4.00	-0.41	-0.73	2.71	-0.86	0.12	-0.23	1.39	0.20	-0.34
5	24.67	3.95	-0.17	-0.43	1.08	-0.52	0.16	-0.10	1.39	0.25	-0.21
6	24.30	3.95	0.15	0.37	1.24	0.41	0.22	-0.12	1.39	0.25	-0.23

MULTIPLE SIPHON GENERATORS
TEST RESULTS : DIFFERENTIAL AND HYDROSTATIC PRESSURES

TEST NUMBER : 180-13
 FLOW PER INTAKE : 15 cumecs
 ANGLE OF APPROACH : 180 deg
 CHANNEL VELOCITY : 0.68 m/s

DATE : 27/11/87
 DEPTH OF SUBMERGENCE : 2.4 m
 WATER DEPTH : 5.51 m
 CHANNEL WIDTH : 32 m

NO OF OPERATING INTAKES : 8
 VORTEX CONDITION : 1
 NOTES : small class 3 @ 0.8
 not reaching intake
 slow recirc. in channel

INTAKE NO.	FLOW (cumecs)	HYDROSTATIC PRESSURE (m)	DIFFERENTIAL HORIZONTAL PRESSURES				DIFFERENTIAL VERTICAL PRESSURES				
			AVERAGE (m)	PRESSURE VARIATIONS			PRESSURE VARIATIONS				
				TYPICAL MAXIMUM (m)	PERIOD (sec)	EXTREME MAXIMUM (m)	TYPICAL L>U (m)	MAXIMUM L<U (m)	PERIOD (sec)	EXTREME L>U (m)	MAXIMUM L<U (m)
1	15.22	4.99	-0.54	-0.82	0.93	-0.88	0.12	-0.19	1.16	0.16	-0.21
2	15.15	4.52	-0.39	-0.65	0.93	-0.69	0.20	-0.06	1.24	0.27	-0.10
3	15.08	4.30	-0.24	-0.43	0.93	-0.52	0.14	-0.03	1.24	0.19	-0.10
4	15.22	4.99	-0.24	-0.41	1.16	-0.49	0.18	-0.06	1.24	0.22	-0.12
5	15.22	4.99	-0.22	-0.37	1.01	-0.43	0.12	-0.03	1.24	0.16	-0.06
6	15.22	4.99	-0.01	-0.32	0.77	-0.37	0.14	-0.06	1.24	0.19	-0.12
7	15.08	4.99	-0.05	-0.19	0.93	-0.30	0.16	-0.03	1.55	0.18	-0.08
8	15.08	5.07	-0.05	-0.17	0.93	-0.22	0.14	-0.03	1.16	0.16	-0.06

TEST NUMBER : 180-14
 FLOW PER INTAKE : 20 cumecs
 ANGLE OF APPROACH : 180 deg
 CHANNEL VELOCITY : 0.91 m/s

DATE : 27/11/87
 DEPTH OF SUBMERGENCE : 2.4 m
 WATER DEPTH : 5.5 m
 CHANNEL WIDTH : 32 m

NO OF OPERATING INTAKES : 8
 VORTEX CONDITION : 1
 NOTES : small class 3 @ 0.8
 slow recirc. in channel

INTAKE NO.	FLOW (cumecs)	HYDROSTATIC PRESSURE (m)	DIFFERENTIAL HORIZONTAL PRESSURES				DIFFERENTIAL VERTICAL PRESSURES				
			AVERAGE (m)	PRESSURE VARIATIONS			PRESSURE VARIATIONS				
				TYPICAL MAXIMUM (m)	PERIOD (sec)	EXTREME MAXIMUM (m)	TYPICAL L>U (m)	MAXIMUM L<U (m)	PERIOD (sec)	EXTREME L>U (m)	MAXIMUM L<U (m)
1	19.96	4.99	-0.75	-1.18	1.94	-1.25	0.31	-0.14	1.08	0.40	-0.25
2	19.96	4.52	-0.73	-1.16	2.32	-1.20	0.33	-0.19	1.16	0.37	-0.19
3	19.86	4.21	-0.52	-0.86	0.93	-0.99	0.25	-0.16	1.01	0.27	-0.27
4	19.86	4.99	-0.41	-0.73	2.71	-0.86	0.22	-0.10	1.55	0.29	-0.19
5	20.11	5.07	-0.31	-0.56	0.77	-0.71	0.20	-0.12	1.01	0.25	-0.16
6	19.96	5.07	-0.22	-0.47	1.16	-0.56	0.18	-0.10	1.55	0.25	-0.19
7	19.84	5.07	-0.11	-0.34	1.55	-0.41	0.25	-0.10	1.55	0.27	-0.23
8	20.16	5.12	0.13	0.30	1.24	0.34	0.12	-0.10	1.55	0.14	-0.12

TEST NUMBER : 180-15
 FLOW PER INTAKE : 40 cumecs
 ANGLE OF APPROACH : 180 deg
 CHANNEL VELOCITY : 0.91 m/s

DATE : 27/11/87
 DEPTH OF SUBMERGENCE : 2.4 m
 WATER DEPTH : 5.51 m
 CHANNEL WIDTH : 32 m

NO OF OPERATING INTAKES : 4
 VORTEX CONDITION : 0
 NOTES :

INTAKE NO.	FLOW (cumecs)	HYDROSTATIC PRESSURE (m)	DIFFERENTIAL HORIZONTAL PRESSURES				DIFFERENTIAL VERTICAL PRESSURES				
			AVERAGE (m)	PRESSURE VARIATIONS			PRESSURE VARIATIONS				
				TYPICAL MAXIMUM (m)	PERIOD (sec)	EXTREME MAXIMUM (m)	TYPICAL L>U (m)	MAXIMUM L<U (m)	PERIOD (sec)	EXTREME L>U (m)	MAXIMUM L<U (m)
1	39.65	4.56	-1.72	-2.58	2.32	-2.75	0.74	-0.46	1.32	0.83	-0.66
2	39.65	4.13	-1.46	-1.64	2.32	-1.85	0.57	-0.49	1.32	0.68	-0.62
3	39.65	3.83	-0.52	-0.95	1.16	-1.16	0.55	-0.27	1.32	-0.66	-0.44
4	39.65	4.60	0.26	0.77	1.24	1.08	0.76	-0.21	1.55	0.98	-0.27

**MULTIPLE SIPHON GENERATORS
TEST RESULTS : DIFFERENTIAL AND HYDROSTATIC PRESSURES**

TEST NUMBER : 180-16
FLOW PER INTAKE : 40 cumecs
ANGLE OF APPROACH : 180 deg
CHANNEL VELOCITY : 2.80 m/s

DATE : 15/01/88
DEPTH OF SUBMERGENCE : 2.4 m
WATER DEPTH : 5.51 m
CHANNEL WIDTH : 20 m

NO OF OPERATING INTAKES : 4
VORTEX CONDITION : 1
NOTES : bubbles at surface near intake 1

INTAKE NO.	FLOW (cumecs)	HYDROSTATIC PRESSURE (m)	DIFFERENTIAL HORIZONTAL PRESSURES				DIFFERENTIAL VERTICAL PRESSURES				
			AVERAGE (m)	PRESSURE VARIATIONS			PRESSURE VARIATIONS				
				TYPICAL MAXIMUM (m)	PERIOD (sec)	EXTREME MAXIMUM (m)	TYPICAL L>U (m)	MAXIMUM L<U (m)	PERIOD (sec)	EXTREME L>U (m)	MAXIMUM L<U (m)
1	39.65	4.55	-2.74	-4.46	1.24	-5.15	1.49	-0.53	1.16	1.87	-0.87
2	39.65	4.81	-2.66	-4.12	1.24	-4.55	1.06	-1.00	1.24	1.45	-1.39
3	39.65	4.98	-1.97	-3.26	1.55	-3.60	0.63	-0.57	1.24	0.84	-0.87
4	39.65	4.94	-1.33	-2.57	1.55	-2.83	0.89	-1.26	1.24	1.32	-1.69

TEST NUMBER : 180-17a
FLOW PER INTAKE : 15 cumecs
ANGLE OF APPROACH : 180 deg
CHANNEL VELOCITY : 3.15 m/s

DATE : 15/01/88
DEPTH OF SUBMERGENCE : 1.2 m
WATER DEPTH : 4.3 m
CHANNEL WIDTH : 20 m

NO OF OPERATING INTAKES : 8
VORTEX CONDITION : 1
NOTES : recirc. inside intakes

INTAKE NO.	FLOW (cumecs)	HYDROSTATIC PRESSURE (m)	DIFFERENTIAL HORIZONTAL PRESSURES				DIFFERENTIAL VERTICAL PRESSURES				
			AVERAGE (m)	PRESSURE VARIATIONS			PRESSURE VARIATIONS				
				TYPICAL MAXIMUM (m)	PERIOD (sec)	EXTREME MAXIMUM (m)	TYPICAL L>U (m)	MAXIMUM L<U (m)	PERIOD (sec)	EXTREME L>U (m)	MAXIMUM L<U (m)
1	15.08	3.48	-1.33	-1.84	1.01	-2.02	0.76	-0.74	1.01	0.95	-1.02
2	15.08	3.56	-1.29	-1.76	1.32	-1.97	0.59	-0.70	1.32	0.84	-0.81
3	15.08	3.65	-1.29	-1.93	1.01	-2.08	0.59	-0.53	1.32	0.89	-0.72
4	15.08	3.71	-1.29	-1.84	1.32	-1.95	0.59	-0.44	1.32	0.74	-0.74
5	15.08	3.78	-1.09	-1.76	1.55	-1.97	0.37	-0.40	1.55	0.54	-0.61
6	15.08	3.80	-0.99	-1.54	1.55	-1.84	0.30	-0.28	1.39	0.39	-0.36
7	15.08	3.84	-1.03	-1.84	1.55	-2.10	0.37	-0.40	1.55	0.59	-0.48
8	15.08	3.86	-0.90	-1.63	1.39	-1.74	0.42	-0.44	1.55	0.52	-0.59

TEST NUMBER : 180-17b
FLOW PER INTAKE : 15 cumecs
ANGLE OF APPROACH : 180 deg
CHANNEL VELOCITY : 2.44 m/s

DATE : 15/01/88
DEPTH OF SUBMERGENCE : 1.2 m
WATER DEPTH : 4.3 m
CHANNEL WIDTH : 20 m

NO OF OPERATING INTAKES : 8
VORTEX CONDITION : 1
NOTES : recirc. in intakes
recirculation in channel

INTAKE NO.	FLOW (cumecs)	HYDROSTATIC PRESSURE (m)	DIFFERENTIAL HORIZONTAL PRESSURES				DIFFERENTIAL VERTICAL PRESSURES				
			AVERAGE (m)	PRESSURE VARIATIONS			PRESSURE VARIATIONS				
				TYPICAL MAXIMUM (m)	PERIOD (sec)	EXTREME MAXIMUM (m)	TYPICAL L>U (m)	MAXIMUM L<U (m)	PERIOD (sec)	EXTREME L>U (m)	MAXIMUM L<U (m)
1	15.08	3.48	-1.03	-1.42	1.32	-1.59	0.54	-0.44	1.32	0.72	-0.57
2	15.08	3.48	-1.01	-1.54	1.55	-1.59	0.37	-0.40	1.32	0.57	-0.61
3	15.08	3.56	-0.99	-1.59	1.39	-1.99	0.35	-0.27	1.32	0.37	-0.31
4	15.08	3.61	-0.79	-1.37	1.55	-1.59	0.35	-0.23	1.39	0.50	-0.48
5	15.08	3.61	-0.71	-1.20	1.39	-1.37	0.29	-0.27	1.55	0.33	-0.38
6	15.08	3.65	-0.64	-1.11	1.55	-1.31	0.22	-0.31	1.47	0.41	-0.40
7	15.08	3.65	-0.64	-1.24	1.55	-1.59	0.29	-0.23	1.55	0.45	-0.33
8	15.08	3.65	-0.34	-0.69	1.55	-0.77	0.18	-0.26	1.55	0.33	-0.32

MULTIPLE SIPHON GENERATORS
TEST RESULTS : DIFFERENTIAL AND HYDROSTATIC PRESSURES

TEST NUMBER : 180-18
FLOW PER INTAKE : 25 cumeecs
ANGLE OF APPROACH : 180 deg
CHANNEL VELOCITY : 2.46 m/s

DATE : 15/01/88
DEPTH OF SUBMERGENCE : 1.2 m
WATER DEPTH : 4.31 m
CHANNEL WIDTH : 20 m

NO OF OPERATING INTAKES : 6
VORTEX CONDITION : 1 (baffle
NOTES : baffle held above
intake 1

INTAKE NO.	FLOW (cumeecs)	HYDROSTATIC PRESSURE (m)	DIFFERENTIAL HORIZONTAL PRESSURES				DIFFERENTIAL VERTICAL PRESSURES				
			AVERAGE (m)	PRESSURE VARIATIONS			PRESSURE VARIATIONS				
				TYPICAL MAXIMUM (m)	PERIOD (sec)	EXTREME MAXIMUM (m)	TYPICAL L>U (m)	MAXIMUM L<U (m)	PERIOD (sec)	EXTREME L>U (m)	MAXIMUM L<U (m)
1	24.99		-0.73	-1.33	1.55	-1.59	0.24	-0.83	1.55	0.54	-0.96
2	24.99										
3	24.99										
4	24.99										
5	24.99										
6	24.99										

TEST NUMBER : 120-1
FLOW PER INTAKE : 5 cumeecs
ANGLE OF APPROACH : 120 deg
CHANNEL VELOCITY : 0.29 m/s

DATE : 2/12/87
DEPTH OF SUBMERGENCE : 1.2 m
WATER DEPTH : 4.3 m
CHANNEL WIDTH : 32 m

NO OF OPERATING INTAKES : 8
VORTEX CONDITION : 0
NOTES :

INTAKE NO.	FLOW (cumeecs)	HYDROSTATIC PRESSURE (m)	DIFFERENTIAL HORIZONTAL PRESSURES				DIFFERENTIAL VERTICAL PRESSURES				
			AVERAGE (m)	PRESSURE VARIATIONS			PRESSURE VARIATIONS				
				TYPICAL MAXIMUM (m)	PERIOD (sec)	EXTREME MAXIMUM (m)	TYPICAL L>U (m)	MAXIMUM L<U (m)	PERIOD (sec)	EXTREME L>U (m)	MAXIMUM L<U (m)
1	4.69	3.47	-0.03	-0.11	0.39	0.15	0.09	-0.01	0.15	0.11	-0.02
2	4.81	3.04	-0.03	-0.09	0.39	0.12	0.10	-0.01	0.04	0.11	-0.02
3	4.81	2.74	-0.04	-0.10	0.93	0.12	0.09	-0.01	0.04	0.10	-0.02
4	4.69	3.47	-0.02	-0.08	0.93	0.09	0.09	0.00	0.04	0.10	-0.01
5	4.93	3.77	-0.03	-0.08	0.39	0.10	0.09	0.00	0.04	0.10	-0.02
6	4.81	3.73	-0.04	-0.09	0.39	0.09	0.09	-0.01	0.04	0.10	-0.02
7	4.81	3.73	-0.03	-0.07	0.39	0.08	0.09	-0.01	0.04	0.10	-0.02
8	4.81	3.73	-0.03	-0.07	0.39	0.08	0.09	-0.01	0.15	0.10	-0.02

TEST NUMBER : 120-2
FLOW PER INTAKE : 15 cumeecs
ANGLE OF APPROACH : 120 deg
CHANNEL VELOCITY : 0.87 m/s

DATE : 2/12/87
DEPTH OF SUBMERGENCE : 1.2 m
WATER DEPTH : 4.3 m
CHANNEL WIDTH : 32 m

NO OF OPERATING INTAKES : 8
VORTEX CONDITION : 1
NOTES :

INTAKE NO.	FLOW (cumeecs)	HYDROSTATIC PRESSURE (m)	DIFFERENTIAL HORIZONTAL PRESSURES				DIFFERENTIAL VERTICAL PRESSURES				
			AVERAGE (m)	PRESSURE VARIATIONS			PRESSURE VARIATIONS				
				TYPICAL MAXIMUM (m)	PERIOD (sec)	EXTREME MAXIMUM (m)	TYPICAL L>U (m)	MAXIMUM L<U (m)	PERIOD (sec)	EXTREME L>U (m)	MAXIMUM L<U (m)
1	15.10	3.73	-0.14	-0.32	1.01	-0.36	0.12	-0.04	1.55	0.12	-0.09
2	15.08	3.30	-0.12	-0.29	1.01	-0.34	0.11	-0.04	1.39	0.14	-0.05
3	15.10	3.00	-0.12	-0.28	1.16	0.32	0.12	-0.03	1.55	0.13	-0.03
4	15.05	3.69	-0.12	-0.27	1.24	-0.34	0.15	-0.03	1.39	0.15	-0.05
5	15.05	3.86	-0.01	-0.14	1.24	-0.26	0.10	-0.03	1.39	0.12	-0.06
6	15.08	3.86	-0.13	-0.28	1.24	-0.34	0.14	-0.06	1.39	0.15	-0.06
7	15.08	3.86	-0.06	-0.21	1.24	-0.24	0.15	-0.04	1.39	0.18	-0.09
8	15.10	3.86	-0.03	-0.17	1.55	-0.20	0.14	-0.05	1.55	0.17	-0.06

**MULTIPLE SIPHON GENERATORS
TEST RESULTS : DIFFERENTIAL AND HYDROSTATIC PRESSURES**

TEST NUMBER : 120-3
FLOW PER INTAKE : 20 cumecs
ANGLE OF APPROACH : 120 deg
CHANNEL VELOCITY : 1.16 m/s

DATE : 03/12/87
DEPTH OF SUBMERGENCE : 1.2 m
WATER DEPTH : 4.3 m
CHANNEL WIDTH : 32 m

NO OF OPERATING INTAKES : 8
VORTEX CONDITION : 0
NOTES :

INTAKE NO.	FLOW (cumecs)	HYDROSTATIC PRESSURE (m)	DIFFERENTIAL HORIZONTAL PRESSURES				DIFFERENTIAL VERTICAL PRESSURES				
			AVERAGE (m)	PRESSURE VARIATIONS			TYPICAL L>U (m)	PRESSURE VARIATIONS			EXTREME L<U (m)
				TYPICAL MAXIMUM (m)	PERIOD (sec)	EXTREME MAXIMUM (m)		MAXIMUM L<U (m)	PERIOD (sec)	EXTREME L>U (m)	
1	19.99	3.06	0.85	-0.29	1.39	-0.32	0.24	-0.09	1.55	0.26	-0.12
2	20.01	2.55	0.85	-0.27	1.39	-0.29	0.21	-0.09	1.39	0.31	-0.11
3	20.06	2.99	-0.32	0.62	1.39	-0.64	0.18	-0.07	1.55	0.23	-0.11
4	20.06	2.98	-0.19	-0.45	1.16	-0.52	0.20	-0.08	1.39	0.24	-0.16
5	20.04	3.28	-0.21	-0.46	1.39	-0.54	0.17	-0.08	1.55	0.19	-0.11
6	20.01	3.32	-0.27	-0.52	1.24	-0.56	0.16	-0.09	1.55	0.19	-0.13
7	20.06	3.28	-0.23	-0.48	1.39	-0.53	0.22	-0.04	1.55	0.25	-0.07
8	20.06	3.28	-0.15	-0.40	1.39	-0.52	0.22	-0.06	1.55	0.24	-0.07

TEST NUMBER : 120-4
FLOW PER INTAKE : 30 cumecs
ANGLE OF APPROACH : 120 deg
CHANNEL VELOCITY : 1.09 m/s

DATE : 03/12/87
DEPTH OF SUBMERGENCE : 1.2 m
WATER DEPTH : 4.3 m
CHANNEL WIDTH : 32 m

NO OF OPERATING INTAKES : 5
VORTEX CONDITION : 0
NOTES :

INTAKE NO.	FLOW (cumecs)	HYDROSTATIC PRESSURE (m)	DIFFERENTIAL HORIZONTAL PRESSURES				DIFFERENTIAL VERTICAL PRESSURES				
			AVERAGE (m)	PRESSURE VARIATIONS			TYPICAL L>U (m)	PRESSURE VARIATIONS			EXTREME L<U (m)
				TYPICAL MAXIMUM (m)	PERIOD (sec)	EXTREME MAXIMUM (m)		MAXIMUM L<U (m)	PERIOD (sec)	EXTREME L>U (m)	
1	30.10	2.76	-1.20	-1.67	2.32	-1.85	0.42	-0.18	1.55	0.55	-0.29
2	30.10	3.19	-0.73	-1.12	2.32	-1.33	0.24	-0.14	1.70	0.29	-0.27
3	30.10	3.23	-0.60	-0.94	1.94	-1.12	0.20	-0.18	1.70	0.37	-0.23
4	30.10	3.23	-0.21	-0.52	1.55	-2.49	0.20	0.15	1.70	0.31	-0.18
5	30.10	3.28	-0.17	-0.47	1.39	-0.56	0.29	-0.14	1.70	-0.29	-0.23

TEST NUMBER : 120-5
FLOW PER INTAKE : 15 cumecs
ANGLE OF APPROACH : 120 deg
CHANNEL VELOCITY : 0.68 m/s

DATE : 03/12/87
DEPTH OF SUBMERGENCE : 2.4 m
WATER DEPTH : 5.51 m
CHANNEL WIDTH : 32 m

NO OF OPERATING INTAKES : 8
VORTEX CONDITION : 0
NOTES :

INTAKE NO.	FLOW (cumecs)	HYDROSTATIC PRESSURE (m)	DIFFERENTIAL HORIZONTAL PRESSURES				DIFFERENTIAL VERTICAL PRESSURES				
			AVERAGE (m)	PRESSURE VARIATIONS			TYPICAL L>U (m)	PRESSURE FLUCTUATIONS			EXTREME L<U (m)
				TYPICAL MAXIMUM (m)	PERIOD (sec)	EXTREME MAXIMUM (m)		MAXIMUM L<U (m)	PERIOD (sec)	EXTREME L>U (m)	
1	15.08	4.01	-0.09	-0.31	1.01	-0.34	0.18	-0.06	0.39	0.21	-0.07
2	14.93	3.66	-0.04	-0.26	1.20	-0.32	0.17	-0.05	0.39	0.18	-0.02
3	15.05	3.32	-0.17	-0.36	1.20	-0.45	0.17	-0.02	0.39	0.18	-0.03
4	15.08	4.01	-0.09	-0.26	1.20	-0.29	0.17	0.00	0.39	0.19	-0.04
5	15.10	4.44	-0.09	-0.23	1.20	-0.26	0.15	-0.02	0.39	0.17	-0.03
6	15.13	4.44	-0.09	-0.26	1.20	-0.27	0.15	-0.06	0.39	0.19	-0.08
7	15.13	4.44	-0.08	-0.22	1.20	-0.25	0.17	-0.06	0.39	0.19	-0.11
8	15.05	4.44	-0.03	-0.21	1.39	-0.22	0.18	-0.06	0.39	0.20	-0.09

MULTIPLE SIPHON GENERATORS
TEST RESULTS : DIFFERENTIAL AND HYDROSTATIC PRESSURES

TEST NUMBER : 120-6
FLOW PER INTAKE : 30 cumecs
ANGLE OF APPROACH : 120 deg
CHANNEL VELOCITY : 0.85 m/s

DATE : 03/12/87
DEPTH OF SUBMERGENCE : 2.4 m
WATER DEPTH : 5.51 m
CHANNEL WIDTH : 32 m

NO OF OPERATING INTAKES : 5
VORTEX CONDITION : 0
NOTES :

INTAKE NO.	FLOW (cumecs)	HYDROSTATIC PRESSURE (m)	DIFFERENTIAL HORIZONTAL PRESSURES				DIFFERENTIAL VERTICAL PRESSURES				
			AVERAGE (m)	PRESSURE VARIATIONS			PRESSURE VARIATIONS				
				TYPICAL MAXIMUM (m)	PERIOD (sec)	EXTREME MAXIMUM (m)	TYPICAL L>U (m)	MAXIMUM L<U (m)	PERIOD (sec)	EXTREME L>U (m)	MAXIMUM L<U (m)
1	29.95	3.75	-0.94	-1.37	2.32	-1.42	0.43	-0.18	1.70	0.49	-0.28
2	29.86	4.35	-0.47	-0.90	1.94	-1.01	0.30	-0.04	1.82	0.43	-0.10
3	29.73	4.35	-0.45	-0.82	1.94	-0.97	0.29	-0.12	1.82	0.39	-0.18
4	30.20	4.35	-0.26	-0.56	1.94	-0.77	0.36	-0.03	1.82	0.42	-0.12
5	30.08	4.35	0.00	0.30	1.55	-0.34	0.43	-0.11	1.94	0.49	-0.17

TEST NUMBER : 120-7
FLOW PER INTAKE : 40 cumecs
ANGLE OF APPROACH : 120 deg
CHANNEL VELOCITY : 0.91 m/s

DATE : 03/12/87
DEPTH OF SUBMERGENCE : 2.4 m
WATER DEPTH : 5.51 m
CHANNEL WIDTH : 32 m

NO OF OPERATING INTAKES : 4
VORTEX CONDITION : 1
NOTES :

INTAKE NO.	FLOW (cumecs)	HYDROSTATIC PRESSURE (m)	DIFFERENTIAL HORIZONTAL PRESSURES				DIFFERENTIAL VERTICAL PRESSURES				
			AVERAGE (m)	PRESSURE VARIATIONS			PRESSURE VARIATIONS				
				TYPICAL MAXIMUM (m)	PERIOD (sec)	EXTREME MAXIMUM (m)	TYPICAL L>U (m)	MAXIMUM L<U (m)	PERIOD (sec)	EXTREME L>U (m)	MAXIMUM L<U (m)
5	39.97	4.27	-1.25	-1.89	1.39	-2.06	0.63	-0.18	1.70	0.67	-0.23
6	39.97	4.27	-0.97	-1.55	1.47	-1.72	0.52	-0.27	1.90	0.59	-0.33
7	39.97	4.27	-0.26	-0.77	1.47	-1.03	0.55	-0.12	1.90	0.61	-0.25
8	39.97	4.35	-0.13	-0.60	1.55	-0.73	0.61	-0.23	2.09	0.76	-0.33

TEST NUMBER : 120-8
FLOW PER INTAKE : 15 cumecs
ANGLE OF APPROACH : 120 deg
CHANNEL VELOCITY : 0.54 m/s

DATE : 01/12/87
DEPTH OF SUBMERGENCE : 2.4 m
WATER DEPTH : 6.91 m
CHANNEL WIDTH : 32 m

NO OF OPERATING INTAKES : 8
VORTEX CONDITION : 0
NOTES : infrequent class 2 at intake 1

INTAKE NO.	FLOW (cumecs)	HYDROSTATIC PRESSURE (m)	DIFFERENTIAL HORIZONTAL PRESSURES				DIFFERENTIAL VERTICAL PRESSURES				
			AVERAGE (m)	PRESSURE VARIATIONS			PRESSURE VARIATIONS				
				TYPICAL MAXIMUM (m)	PERIOD (sec)	EXTREME MAXIMUM (m)	TYPICAL L>U (m)	MAXIMUM L<U (m)	PERIOD (sec)	EXTREME L>U (m)	MAXIMUM L<U (m)
1	15.05	4.80	-0.03	-0.29	0.77	-0.35	0.15	-0.06	1.55	0.19	0.33
2	15.08	4.19	-0.07	-0.27	0.97	-0.29	0.15	-0.06	1.63	0.19	0.33
3	15.10	4.02	-0.06	-0.29	0.97	-0.42	0.13	-0.04	1.63	0.14	-0.06
4	15.08	4.88	-0.04	-0.30	0.97	-0.34	0.17	-0.06	1.63	0.19	-0.06
5	15.08	4.97	-0.05	-0.21	0.97	-0.26	0.12	-0.03	1.63	0.15	-0.06
6	15.05	5.01	-0.08	-0.28	0.97	-0.31	0.12	-0.06	1.63	0.14	-0.06
7	15.10	5.01	-0.05	-0.27	0.97	-0.32	0.17	-0.07	1.63	0.19	-0.09
8	15.08	5.01	-0.08	-0.21	1.16	-0.22	0.13	-0.05	1.70	-0.12	-0.09

MULTIPLE SIPHON GENERATORS
TEST RESULTS : DIFFERENTIAL AND HYDROSTATIC PRESSURES

TEST NUMBER : 120-9
 FLOW PER INTAKE : 30 cumecs
 ANGLE OF APPROACH : 120 deg
 CHANNEL VELOCITY : 0.82 m/s

DATE : 02/12/87
 DEPTH OF SUBMERGENCE : 1.2 m
 WATER DEPTH : 5.71 m
 CHANNEL WIDTH : 32 m

NO OF OPERATING INTAKES : 5
 VORTEX CONDITION : 2
 NOTES : infrequent class 3 @ 4,5
 not entering intakes

INTAKE NO.	FLOW (cumecs)	HYDROSTATIC PRESSURE (m)	DIFFERENTIAL HORIZONTAL PRESSURES				DIFFERENTIAL VERTICAL PRESSURES				
			AVERAGE (m)	PRESSURE VARIATIONS			PRESSURE FLUCTUATIONS				
				TYPICAL MAXIMUM (m)	PERIOD (sec)	EXTREME MAXIMUM (m)	TYPICAL L>U (m)	MAXIMUM L<U (m)	PERIOD (sec)	EXTREME L>U (m)	MAXIMUM L<U (m)
1	30.35	3.34	-0.71	-1.23	1.16	-1.31	0.33	-0.19	1.70	0.37	-0.30
2	30.35	3.69	-4.31	-0.86	1.35	-0.93	0.26	-0.45	1.74	0.34	-0.45
3	30.35	3.73	-0.32	-0.65	1.35	-0.77	-0.16	-0.33	1.74	0.26	-0.38
4	30.35	3.77	-0.17	-0.47	1.35	-0.62	-0.07	-0.23	1.74	0.20	-0.32
5	30.35	3.77	-0.11	-0.43	1.55	-0.52	-0.19	-0.35	1.78	0.43	-0.57

TEST NUMBER : 120-10
 FLOW PER INTAKE : 30 cumecs
 ANGLE OF APPROACH : 120 deg
 CHANNEL VELOCITY : 1.74 m/s

DATE : 15/12/87
 DEPTH OF SUBMERGENCE : 1.2 m
 WATER DEPTH : 4.31 m
 CHANNEL WIDTH : 20 m

NO OF OPERATING INTAKES : 5
 VORTEX CONDITION : 2
 NOTES : periodic class 3 @ 1,2
 class 4 & 5 @ intake 5

INTAKE NO.	FLOW (cumecs)	HYDROSTATIC PRESSURE (m)	DIFFERENTIAL HORIZONTAL PRESSURES				DIFFERENTIAL VERTICAL PRESSURES				
			AVERAGE (m)	PRESSURE VARIATIONS			PRESSURE VARIATIONS				
				TYPICAL MAXIMUM (m)	PERIOD (sec)	EXTREME MAXIMUM (m)	TYPICAL L>U (m)	MAXIMUM L<U (m)	PERIOD (sec)	EXTREME L>U (m)	MAXIMUM L<U (m)
1	29.91	0.03	-0.33	-0.75	1.55	-0.90	0.36	-0.30	1.32	0.55	-0.35
2	29.91	3.23	-0.27	-0.63	1.74	-0.77	0.41	-0.35	1.43	0.53	-0.43
3	29.91	3.27	-0.33	-0.67	1.74	-0.75	0.32	-0.30	1.43	0.32	-0.39
4	29.91	3.27	-0.21	-0.50	1.74	-0.50	0.36	-0.39	1.43	0.49	-0.39
5	29.91	3.27	-0.15	-0.46	1.94	-0.50	0.36	-0.26	1.55	0.45	-0.33

TEST NUMBER : 120-11
 FLOW PER INTAKE : 30 cumecs
 ANGLE OF APPROACH : 120 deg
 CHANNEL VELOCITY : 1.36 m/s

DATE : 15/12/87
 DEPTH OF SUBMERGENCE : 2.4 m
 WATER DEPTH : 5.51 m
 CHANNEL WIDTH : 20 m

NO OF OPERATING INTAKES : 5
 VORTEX CONDITION : 2
 NOTES : infrequent class 3 @ 1,2
 periodic class 3&4 @ 5
 with occasional class 5;
 vortex in channel corners

INTAKE NO.	FLOW (cumecs)	HYDROSTATIC PRESSURE (m)	DIFFERENTIAL HORIZONTAL PRESSURES				DIFFERENTIAL VERTICAL PRESSURES				
			AVERAGE (m)	PRESSURE VARIATIONS			PRESSURE VARIATIONS				
				TYPICAL MAXIMUM (m)	PERIOD (sec)	EXTREME MAXIMUM (m)	TYPICAL L>U (m)	MAXIMUM L<U (m)	PERIOD (sec)	EXTREME L>U (m)	MAXIMUM L<U (m)
1	30.10	4.40	-0.40	-0.84	1.39	-0.92	0.48	-0.22	1.16	0.50	-0.24
2	30.10	4.32	-0.25	-0.54	1.47	-0.67	0.31	-0.35	1.35	0.40	-0.40
3	30.10	4.32	-0.13	-0.56	1.47	-0.71	0.35	-0.32	1.35	0.41	-0.40
4	30.10	4.48	-0.08	-0.46	1.47	-0.59	0.41	-0.30	1.35	0.48	-0.39
5	30.10	4.48	-0.06	-0.38	1.55	-0.48	0.33	-0.39	1.55	0.33	-0.41

MULTIPLE SIPHON GENERATORS
TEST RESULTS : DIFFERENTIAL AND HYDROSTATIC PRESSURES

TEST NUMBER : 120-12
FLOW PER INTAKE : 40 cumecs
ANGLE OF APPROACH : 120 deg
CHANNEL VELOCITY : 1.45 m/s

DATE : 15/12/87
DEPTH OF SUBMERGENCE : 1.2 m
WATER DEPTH : 5.51 m
CHANNEL WIDTH : 20 m

NO OF OPERATING INTAKES : 4
VORTEX CONDITION : 3
NOTES : occasional class 3
at all intakes ;
occasional class 4,5
at intake 4

INTAKE NO.	FLOW (cumecs)	HYDROSTATIC PRESSURE (m)	DIFFERENTIAL HORIZONTAL PRESSURES				DIFFERENTIAL VERTICAL PRESSURES				
			AVERAGE (m)	PRESSURE VARIATIONS			PRESSURE VARIATIONS				
				TYPICAL MAXIMUM (m)	PERIOD (sec)	EXTREME MAXIMUM (m)	TYPICAL L>U (m)	MAXIMUM L<U (m)	PERIOD (sec)	EXTREME L>U (m)	MAXIMUM L<U (m)
1	39.97	4.38	-0.95	-1.65	1.55	-1.95	0.68	-0.58	1.32	0.92	-0.90
2	39.97	4.47	-0.65	-1.30	1.55	-1.52	0.59	-0.53	1.35	0.85	-0.84
3	39.97	4.47	-0.22	-0.69	1.55	-0.78	0.46	-0.36	1.35	0.68	-0.40
4	39.97	4.56	-0.09	-0.61	1.55	0.61	0.68	-0.53	1.39	0.85	-1.10

TEST NUMBER : 120-13
FLOW PER INTAKE : 30 cumecs
ANGLE OF APPROACH : 120 deg
CHANNEL VELOCITY : 1.32 m/s

DATE : 08/12/87
DEPTH OF SUBMERGENCE : 1.2 m
WATER DEPTH : 5.71 m
CHANNEL WIDTH : 20 m

NO OF OPERATING INTAKES : 5
VORTEX CONDITION : 3
NOTES : class 2,3,occasional 4
at intakes 1,2,3,5;
class 2,3 @ 4

INTAKE NO.	FLOW (cumecs)	HYDROSTATIC PRESSURE (m)	DIFFERENTIAL HORIZONTAL PRESSURES				DIFFERENTIAL VERTICAL PRESSURES				
			AVERAGE (m)	PRESSURE VARIATIONS			PRESSURE VARIATIONS				
				TYPICAL MAXIMUM (m)	PERIOD (sec)	EXTREME MAXIMUM (m)	TYPICAL L>U (m)	MAXIMUM L<U (m)	PERIOD (sec)	EXTREME L>U (m)	MAXIMUM L<U (m)
1	30.15	3.21	0.24	0.64	1.70	0.81	0.31	-0.25	1.70	0.34	-0.40
2	30.15	3.21	0.24	0.60	1.70	0.73	0.32	-0.26	1.70	0.51	-0.40
3	30.15	3.34	0.15	0.51	1.70	-0.54	0.30	-0.24	1.70	0.34	-0.35
4	30.15	3.38	0.15	0.47	1.70	0.60	0.30	-0.14	1.70	0.39	-0.14
5	30.15	3.38	-0.11	-0.43	1.70	-0.60	0.42	-0.31	1.70	0.51	-0.43

TEST NUMBER : 120-14
FLOW PER INTAKE : 30 cumecs
ANGLE OF APPROACH : 120 deg
CHANNEL VELOCITY : 1.09 m/s

DATE : 07/12/87
DEPTH OF SUBMERGENCE : 2.4 m
WATER DEPTH : 6.91 m
CHANNEL WIDTH : 20 m

NO OF OPERATING INTAKES : 5
VORTEX CONDITION : 2
NOTES : occasional class 3
at intakes 1,2,5

INTAKE NO.	FLOW (cumecs)	HYDROSTATIC PRESSURE (m)	DIFFERENTIAL HORIZONTAL PRESSURES				DIFFERENTIAL VERTICAL PRESSURES				
			AVERAGE (m)	PRESSURE VARIATIONS			PRESSURE VARIATIONS				
				TYPICAL MAXIMUM (m)	PERIOD (sec)	EXTREME MAXIMUM (m)	TYPICAL L>U (m)	MAXIMUM L<U (m)	PERIOD (sec)	EXTREME L>U (m)	MAXIMUM L<U (m)
1	29.91	5.23	-0.39	-0.81	1.55	-0.94	0.30	-0.09	1.55	0.42	-0.42
2	29.86	5.23	-0.24	-0.60	1.55	-0.73	0.24	-0.75	1.55	0.32	-0.42
3	30.18	5.23	-0.13	-0.56	1.55	-0.71	0.32	-0.23	1.55	0.40	-0.30
4	30.20	5.32	0.06	0.43	1.55	0.56	0.32	-0.09	1.55	0.39	-0.12
5	30.08	5.32	-0.17	-0.51	1.55	-0.62	0.39	-0.30	1.55	0.49	-0.43

MULTIPLE SIPHON GENERATORS
TEST RESULTS : DIFFERENTIAL AND HYDROSTATIC PRESSURES

TEST NUMBER : 120-15
FLOW PER INTAKE : 40 cumecs
ANGLE OF APPROACH : 120 deg
CHANNEL VELOCITY : 1.16 m/s

DATE : 07/12/87
DEPTH OF SUBMERGENCE : 2.4 m
WATER DEPTH : 6.91 m
CHANNEL WIDTH : 20 m

NO OF OPERATING INTAKES : 4
VORTEX CONDITION : 2,3
NOTES : at intakes 3,4
vortex not entering
intakes

INTAKE NO.	FLOW (cumecs)	HYDROSTATIC PRESSURE (m)	DIFFERENTIAL HORIZONTAL PRESSURES				DIFFERENTIAL VERTICAL PRESSURES				
			AVERAGE (m)	PRESSURE VARIATIONS			PRESSURE VARIATIONS				
				TYPICAL MAXIMUM (m)	PERIOD (sec)	EXTREME MAXIMUM (m)	TYPICAL L>U (m)	MAXIMUM L<U (m)	PERIOD (sec)	EXTREME L>U (m)	MAXIMUM L<U (m)
1	39.85	4.41	-0.81	-1.50	1.55	-1.61	0.29	-0.38	2.01	0.43	-0.42
2	39.85	4.41	-0.45	-1.16	1.66	-1.27	0.42	-0.45	1.97	0.44	-0.61
3	39.85	4.50	-0.04	-0.69	1.66	-0.77	0.37	-0.14	1.97	0.50	-0.23
4	39.85	4.50	-0.02	0.81	1.78	-0.86	0.50	-0.61	1.94	0.57	-0.96

TEST NUMBER : 150-1
FLOW PER INTAKE : 5 cumecs
ANGLE OF APPROACH : 150 deg
CHANNEL VELOCITY : 0.49 m/s

DATE : 05/01/88
DEPTH OF SUBMERGENCE : 1.2 m
WATER DEPTH : 4.31 m
CHANNEL WIDTH : 19 m

NO OF OPERATING INTAKES : 8
VORTEX CONDITION : 0
NOTES :

INTAKE NO.	FLOW (cumecs)	HYDROSTATIC PRESSURE (m)	DIFFERENTIAL HORIZONTAL PRESSURES				DIFFERENTIAL VERTICAL PRESSURES				
			AVERAGE (m)	PRESSURE VARIATIONS			PRESSURE VARIATIONS				
				TYPICAL MAXIMUM (m)	PERIOD (sec)	EXTREME MAXIMUM (m)	TYPICAL L>U (m)	MAXIMUM L<U (m)	PERIOD (sec)	EXTREME L>U (m)	MAXIMUM L<U (m)
1	5.43	3.47	-9.43	-0.19	0.19	-0.20	0.15	-0.08	0.05	0.16	-0.09
2	4.93	3.47	-5.14	-0.15	0.15	-0.17	0.09	-0.03	0.08	-0.04	-0.03
3	5.06	3.47	-5.14	-0.20	0.15	-0.22	0.17	-0.10	0.15	0.18	-0.12
4	4.93	3.42	-6.86	-0.13	0.19	-0.14	0.09	-0.05	0.04	0.10	-0.05
5	5.06	3.38	-6.86	-0.16	0.15	-0.18	0.22	-0.17	0.15	0.25	-0.19
6	5.06	3.42	-8.14	-0.15	0.15	-0.16	0.09	-0.04	0.08	0.10	-0.05
7	5.06	3.42	-4.71	-0.20	0.31	-0.21	0.11	-0.04	0.08	0.12	-0.06
8	5.06	3.47	-1.71	-0.14	0.31	-0.17	0.12	-0.06	0.15	0.13	-0.08

TEST NUMBER : 150-2
FLOW PER INTAKE : 20 cumecs
ANGLE OF APPROACH : 150 deg
CHANNEL VELOCITY : 1.96 m/s

DATE : 06/01/88
DEPTH OF SUBMERGENCE : 1.2 m
WATER DEPTH : 4.31 m
CHANNEL WIDTH : 19 m

NO OF OPERATING INTAKES : 8
VORTEX CONDITION : 1
NOTES :

INTAKE NO.	FLOW (cumecs)	HYDROSTATIC PRESSURE (m)	DIFFERENTIAL HORIZONTAL PRESSURES				DIFFERENTIAL VERTICAL PRESSURES				
			AVERAGE (m)	PRESSURE VARIATIONS			PRESSURE VARIATIONS				
				TYPICAL MAXIMUM (m)	PERIOD (sec)	EXTREME MAXIMUM (m)	TYPICAL L>U (m)	MAXIMUM L<U (m)	PERIOD (sec)	EXTREME L>U (m)	MAXIMUM L<U (m)
1	19.94	3.64	-0.82	-1.21	1.55	-1.36	0.29	-0.14	1.94	0.33	-0.21
2	20.06	3.64	-0.84	-1.56	1.55	-1.73	0.26	-0.21	1.94	0.34	-0.23
3	20.11	3.64	-1.17	-1.82	1.55	-1.90	0.22	-0.16	2.32	0.28	-0.19
4	20.01	3.59	-1.06	-1.64	1.94	-1.73	0.24	-0.11	2.32	0.31	-0.13
5	19.96	3.55	-0.99	-1.51	2.01	-1.56	0.24	-0.09	2.32	0.30	-0.17
6	20.04	3.59	-0.93	-1.47	2.32	-1.60	0.17	-0.16	2.32	0.20	-0.23
7	19.91	3.59	-0.69	-1.17	2.32	-1.30	0.22	-0.11	2.32	0.25	-0.19
8	20.01	3.64	-0.09	-0.78	2.32	-0.97	0.24	-0.18	2.32	0.30	-0.23

MULTIPLE SIPHON GENERATORS
TEST RESULTS : DIFFERENTIAL AND HYDROSTATIC PRESSURES

TEST NUMBER : 150-3
FLOW PER INTAKE : 25 cumeecs
ANGLE OF APPROACH : 150 deg
CHANNEL VELOCITY : 1.84 m/s

DATE : 06/01/88
DEPTH OF SUBMERGENCE : 1.2 m
WATER DEPTH : 4.31 m
CHANNEL WIDTH : 19 m

NO OF OPERATING INTAKES : 6
VORTEX CONDITION : 1
NOTES :

INTAKE NO.	FLOW (cumeecs)	HYDROSTATIC PRESSURE (m)	DIFFERENTIAL HORIZONTAL PRESSURES				DIFFERENTIAL VERTICAL PRESSURES				
			AVERAGE (m)	PRESSURE VARIATIONS			PRESSURE VARIATIONS				
				TYPICAL MAXIMUM (m)	PERIOD (sec)	EXTREME MAXIMUM (m)	TYPICAL L>U (m)	MAXIMUM L<U (m)	PERIOD (sec)	EXTREME L>U (m)	MAXIMUM L<U (m)
1	24.92	3.68	-0.76	-1.17	1.94	-1.34	0.34	-0.25	2.32	0.39	-0.32
2	24.92	3.72	-0.76	-1.30	2.32	-1.64	0.24	-0.24	2.32	0.29	-0.26
3	24.92	3.72	-0.99	-1.64	2.32	-1.86	0.31	-0.14	2.32	0.36	-0.21
4	24.92	3.77	-0.78	-1.30	2.32	-1.45	0.25	-0.09	2.32	0.30	-0.13
5	24.92	3.77	-0.63	-1.02	1.94	-1.10	0.20	-0.16	2.32	0.25	-0.23
6	24.92	3.77	-0.39	-0.74	1.94	-0.86	0.24	0.24	2.32	0.29	-0.24

TEST NUMBER : 150-5
FLOW PER INTAKE : 40 cumeecs
ANGLE OF APPROACH : 150 deg
CHANNEL VELOCITY : 1.53 m/s

DATE : 17/12/87
DEPTH OF SUBMERGENCE : 2.4 m
WATER DEPTH : 5.51 m
CHANNEL WIDTH : 19 m

NO OF OPERATING INTAKES : 4
VORTEX CONDITION : 1
NOTES : vortex class 3 in d/s cnr

INTAKE NO.	FLOW (cumeecs)	HYDROSTATIC PRESSURE (m)	DIFFERENTIAL HORIZONTAL PRESSURES				DIFFERENTIAL VERTICAL PRESSURES				
			AVERAGE (m)	PRESSURE VARIATIONS			PRESSURE FLUCTUATIONS				
				TYPICAL MAXIMUM (m)	PERIOD (sec)	EXTREME MAXIMUM (m)	TYPICAL L>U (m)	MAXIMUM L<U (m)	PERIOD (sec)	EXTREME L>U (m)	MAXIMUM L<U (m)
1	39.79	4.61	-1.62	-3.24	1.94	-3.75	0.46	-0.21	3.10	0.58	-0.31
2	39.79	4.70	-1.19	-2.39	2.01	-2.64	0.63	-0.10	2.71	0.80	-0.25
3	39.79	4.70	-0.47	-1.45	1.94	-1.62	0.27	-0.23	3.10	0.34	-0.34
4	39.79	4.53	-0.51	-1.02	1.94	-1.11	0.50	-0.74	3.10	0.63	-1.04

TEST NUMBER : 150-8
FLOW PER INTAKE : 25 cumeecs
ANGLE OF APPROACH : 150 deg
CHANNEL VELOCITY : 2.42 m/s

DATE : 07/01/88
DEPTH OF SUBMERGENCE : 1.2 m
WATER DEPTH : 4.31 m
CHANNEL WIDTH : 12 m

NO OF OPERATING INTAKES : 5
VORTEX CONDITION : 2
NOTES : random bubbles entering intakes

INTAKE NO.	FLOW (cumeecs)	HYDROSTATIC PRESSURE (m)	DIFFERENTIAL HORIZONTAL PRESSURES				DIFFERENTIAL VERTICAL PRESSURES				
			AVERAGE (m)	PRESSURE VARIATIONS			PRESSURE VARIATIONS				
				TYPICAL MAXIMUM (m)	PERIOD (sec)	EXTREME MAXIMUM (m)	TYPICAL L>U (m)	MAXIMUM L<U (m)	PERIOD (sec)	EXTREME L>U (m)	MAXIMUM L<U (m)
1	25.27	3.42	-1.39	-2.34	1.32	-2.43	0.29	-0.20	1.16	0.41	-0.25
2	25.27	3.42	-1.52	-2.95	1.16	-3.08	0.40	-0.27	1.35	0.55	-0.40
3	25.27	3.46	-1.73	-2.69	1.16	-3.04	0.40	0.23	1.35	0.40	-0.25
4	25.27	3.37	-1.78	-2.69	1.16	-3.04	0.25	0.20	1.35	0.33	-0.23
5	25.27	3.33	-1.21	-2.00	1.01	-2.17	0.55	-0.27	1.55	0.77	-0.45

MULTIPLE SIPHON GENERATORS
TEST RESULTS : DIFFERENTIAL AND HYDROSTATIC PRESSURES

TEST NUMBER : 150-9
FLOW PER INTAKE : 40 cumecs
ANGLE OF APPROACH : 150 deg
CHANNEL VELOCITY : 2.42 m/s

DATE : 07/01/88
DEPTH OF SUBMERGENCE : 2.4 m
WATER DEPTH : 5.51 m
CHANNEL WIDTH : 12 m

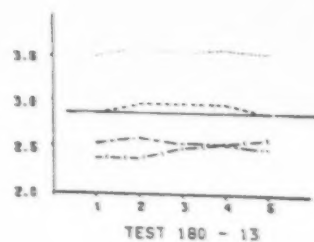
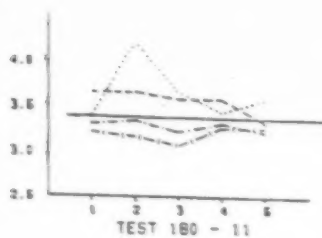
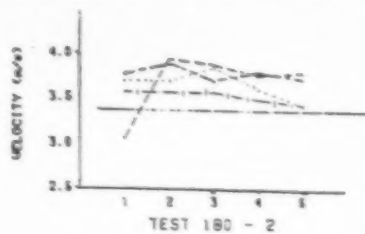
NO OF OPERATING INTAKES : 4
VORTEX CONDITION : 1
NOTES : class 3 vortex in d/s
cnr reaching # 4 via
bottom of intake

INTAKE NO.	FLOW (cumecs)	HYDROSTATIC PRESSURE (m)	DIFFERENTIAL HORIZONTAL PRESSURES				DIFFERENTIAL VERTICAL PRESSURES				
			AVERAGE (m)	PRESSURE VARIATIONS			PRESSURE VARIATIONS				
				TYPICAL MAXIMUM (m)	PERIOD (sec)	EXTREME MAXIMUM (m)	TYPICAL L>U (m)	MAXIMUM L<U (m)	PERIOD (sec)	EXTREME L>U (m)	MAXIMUM L<U (m)
1	40.14	4.53	-1.99	-3.21	1.24	-3.34	0.94	-0.58	1.24	1.20	-0.79
2	40.14	4.70	-1.99	-3.21	1.39	-3.60	-0.63	-0.23	1.39	0.84	-0.45
3	40.14	4.70	-1.91	-3.38	1.39	-3.90	0.72	-0.23	1.39	0.77	-0.40
4	40.14	4.70	-0.74	-2.00	1.55	-2.17	1.16	-0.58	1.55	1.50	-1.36

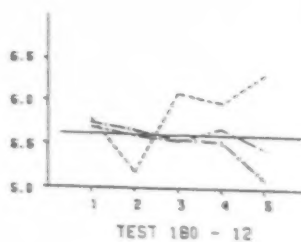
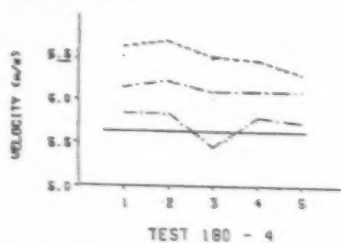
APPENDIX B

Test Results: Intake Velocity Measurements

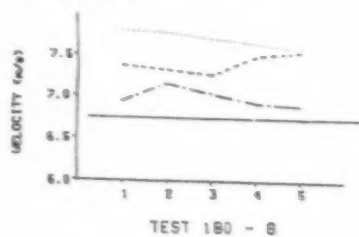
$Q = 15 \text{ m}^3/\text{s}$ 180° APPROACH ANGLE



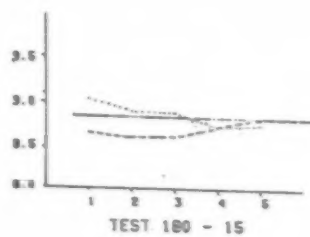
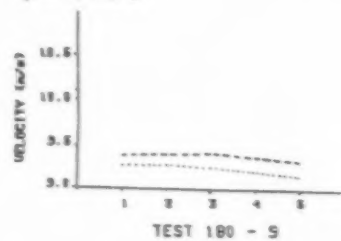
$Q = 25 \text{ m}^3/\text{s}$



$Q = 30 \text{ m}^3/\text{s}$



$Q = 40 \text{ m}^3/\text{s}$

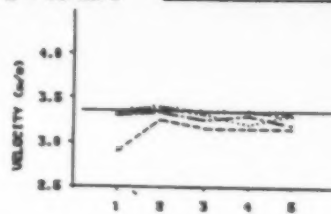


Note
 — AVERAGE VELOCITY
 - - - Intake 1
 - - - Intake 3
 - - - Intake 5
 - - - Intake 8

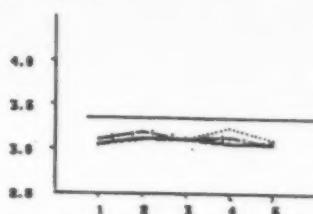
Horizontal axis shows location of velocity measurements in intake.
 All measurements taken at mid depth.

MULTIPLE SIPHON GENERATORS
 APPENDIX B
 INTAKE VELOCITY MEASUREMENTS

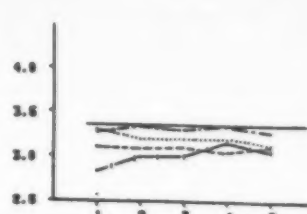
$Q = 15 \text{ m}^3/\text{s}$ 120° APPROACH ANGLE



TEST 120 - 2

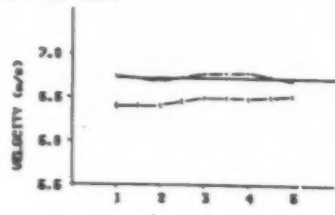


TEST 120 - 5

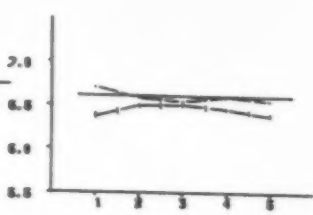


TEST 120 - 8

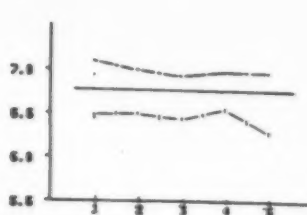
$Q = 30 \text{ m}^3/\text{s}$



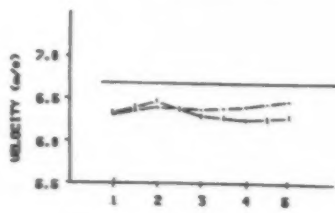
TEST 120 - 4



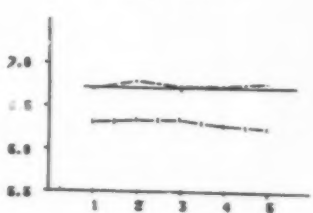
TEST 120 - 6



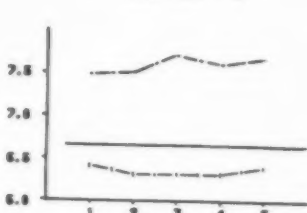
TEST 120 - 9



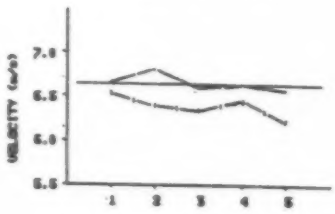
TEST 120 - 10



TEST 120 - 11

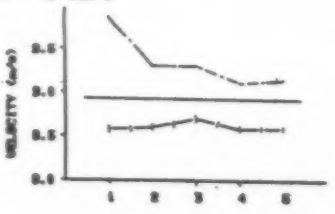


TEST 120 - 13

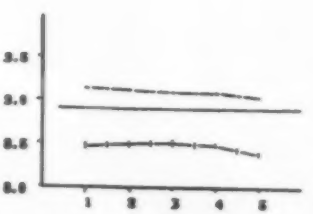


TEST 120 - 14

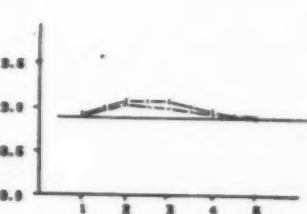
$Q = 40 \text{ m}^3/\text{s}$



TEST 120 - 7



TEST 120 - 12



TEST 120 - 15

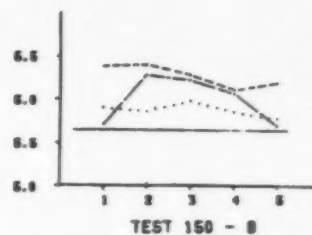
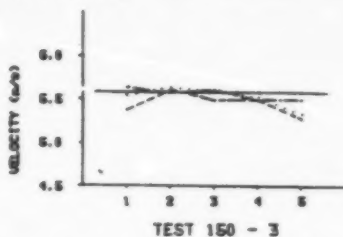
Note

- Average velocity
- - - Intake 1
- - - Intake 3
- - - Intake 5
- - - Intake 8

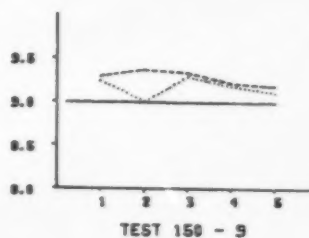
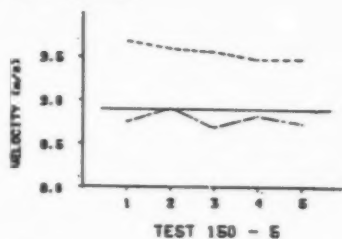
Horizontal axis shows location of velocity measurements in intake.

MATTHEW STERN SENIORS
APPENDIX B
INTAKE VELOCITY MEASUREMENTS

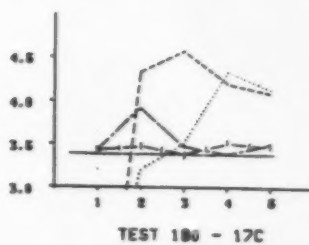
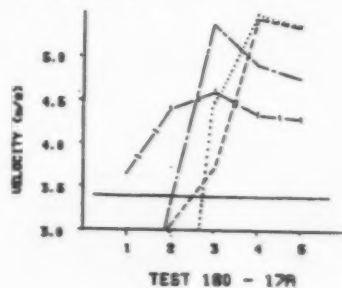
$Q = 25 \text{ m}^3/\text{s}$ 150° APPROACH ANGLE



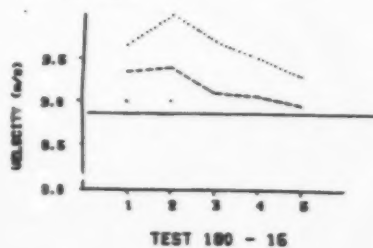
$Q = 40 \text{ m}^3/\text{s}$



$Q = 15 \text{ m}^3/\text{s}$ 180° APPROACH ANGLE (WITH CHANNEL FLOW PAST INTAKES)



$Q = 40 \text{ m}^3/\text{s}$



Note
 — Average velocity
 - - - Intake 1
 - - - Intake 3
 - - - Intake 5
 - - - Intake 8
 Horizontal axis shows location of velocity measurements in intake.